A CAHNERS PUBLICATION
INTERNATIONAL EDITION
FEBRUARY 19, 1987

EDN

IC provides 100-MHz rms/dc conversion

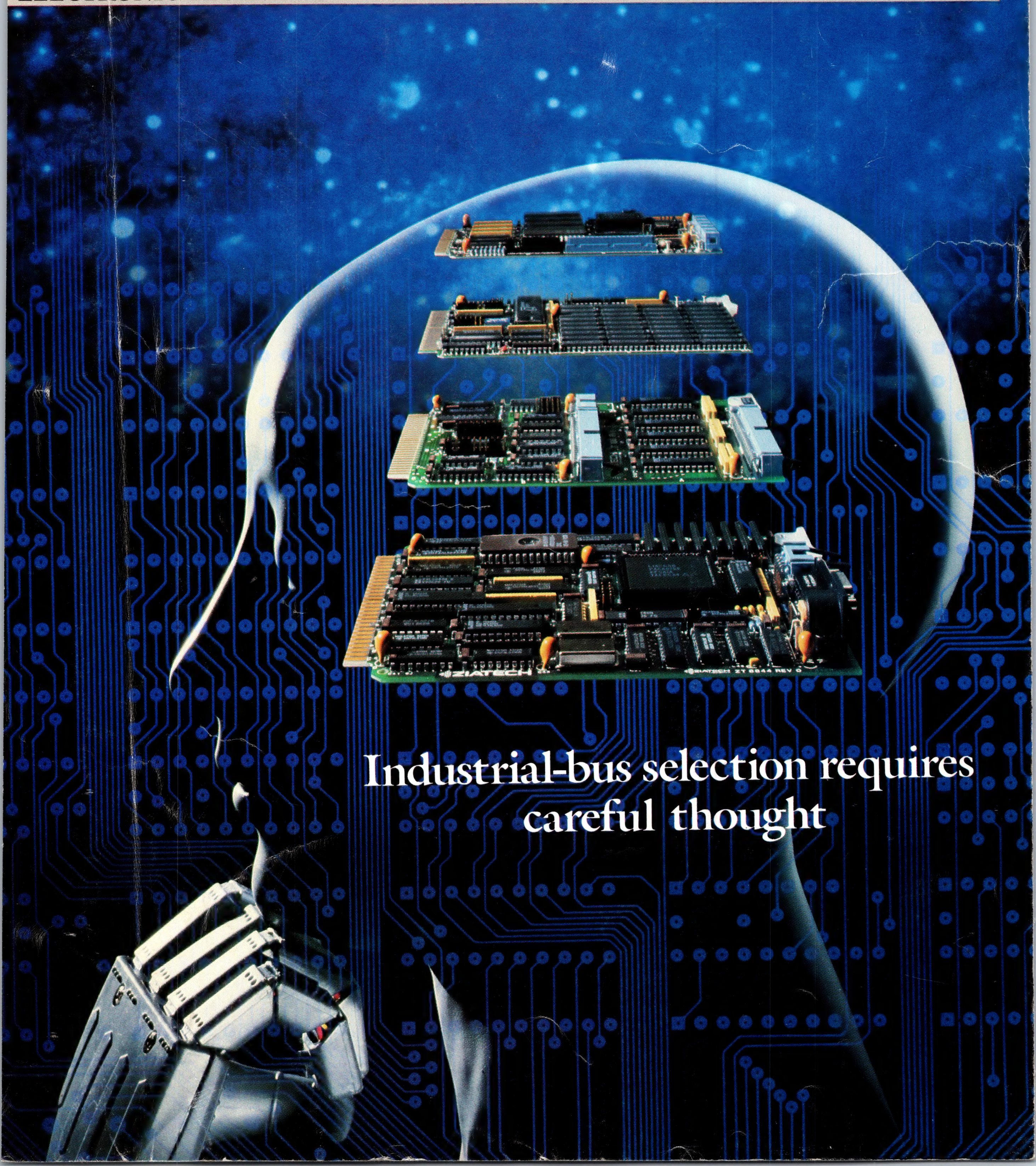
Ada compiler runs on IBM PC/AT

AI boosts utility of CAE/CAD tools

Analog multipliers

23 APR REC'D

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



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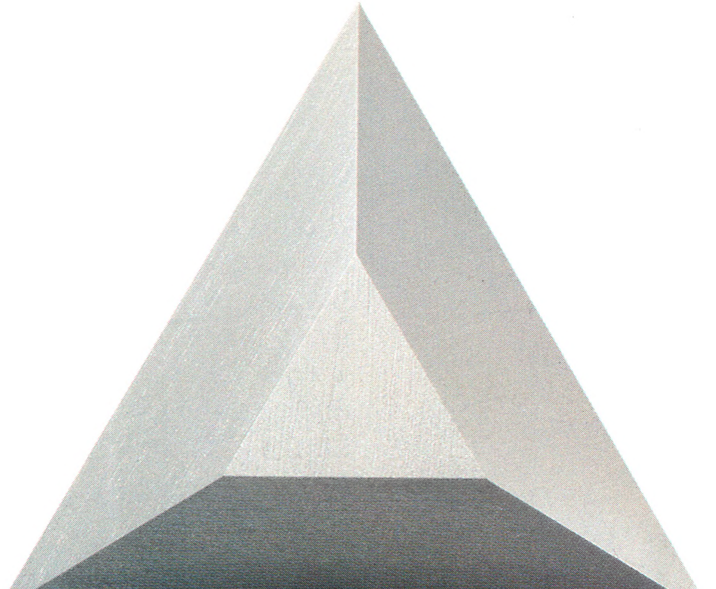

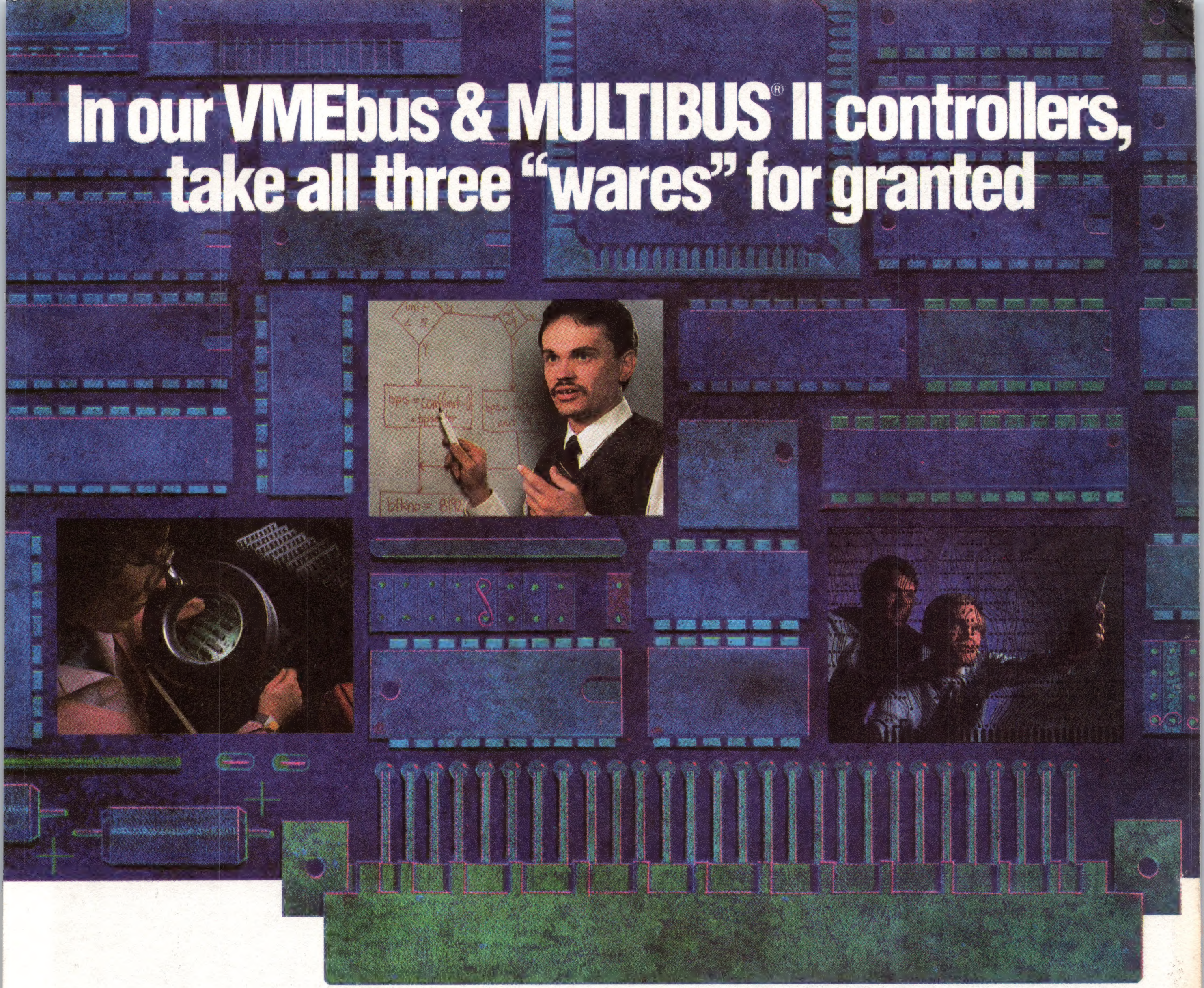
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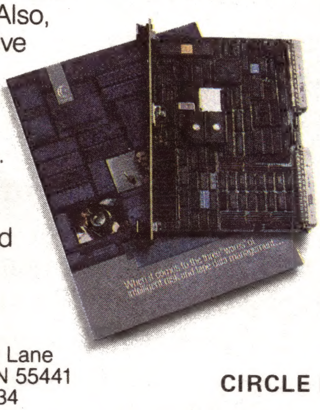

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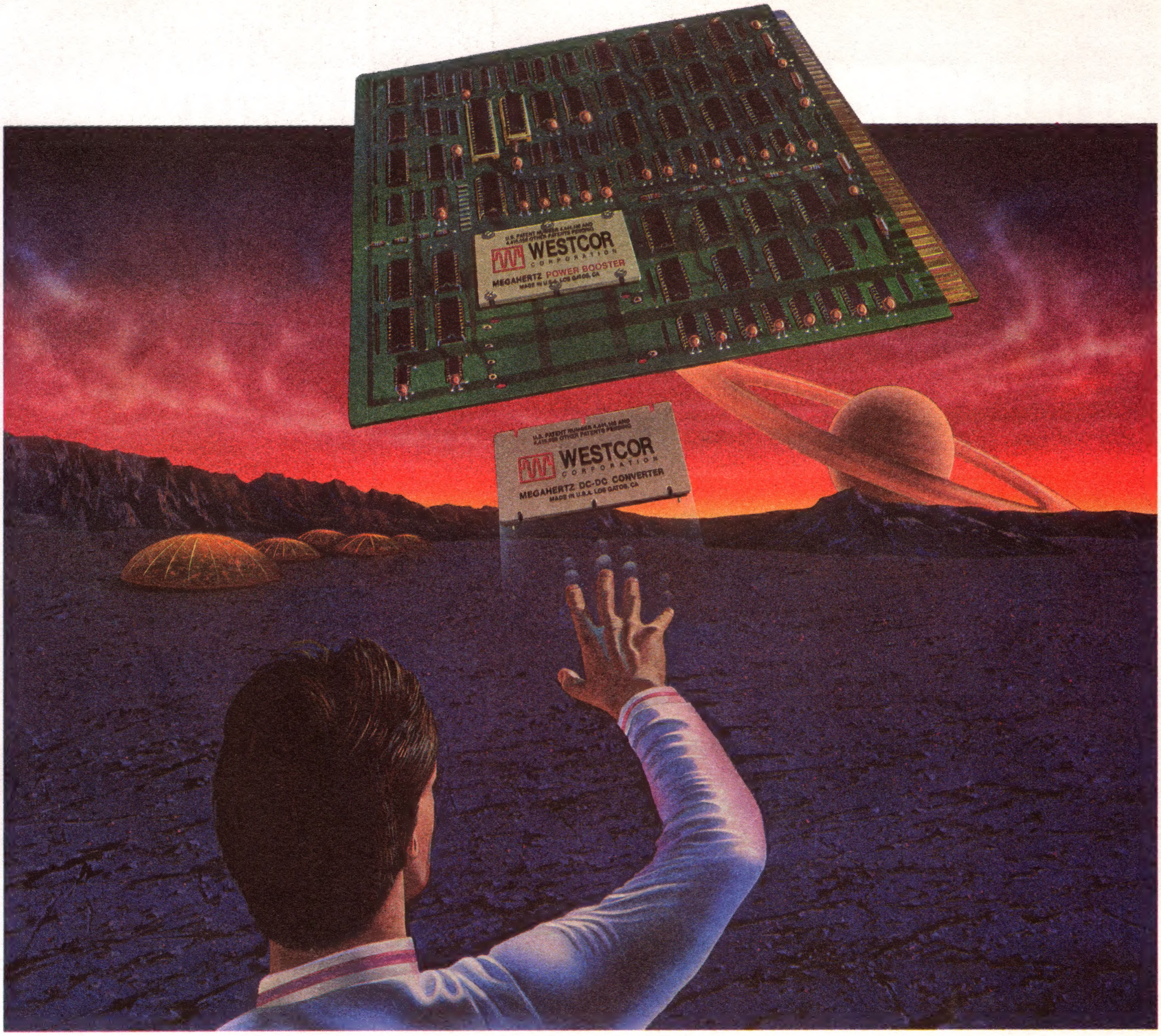
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For more information, call us at (619) 279-2200, or write Wavetek San Diego, Inc., 9045 Balboa Ave., P.O. Box 85265, San Diego, CA 92138. TWX 910-335-2007.

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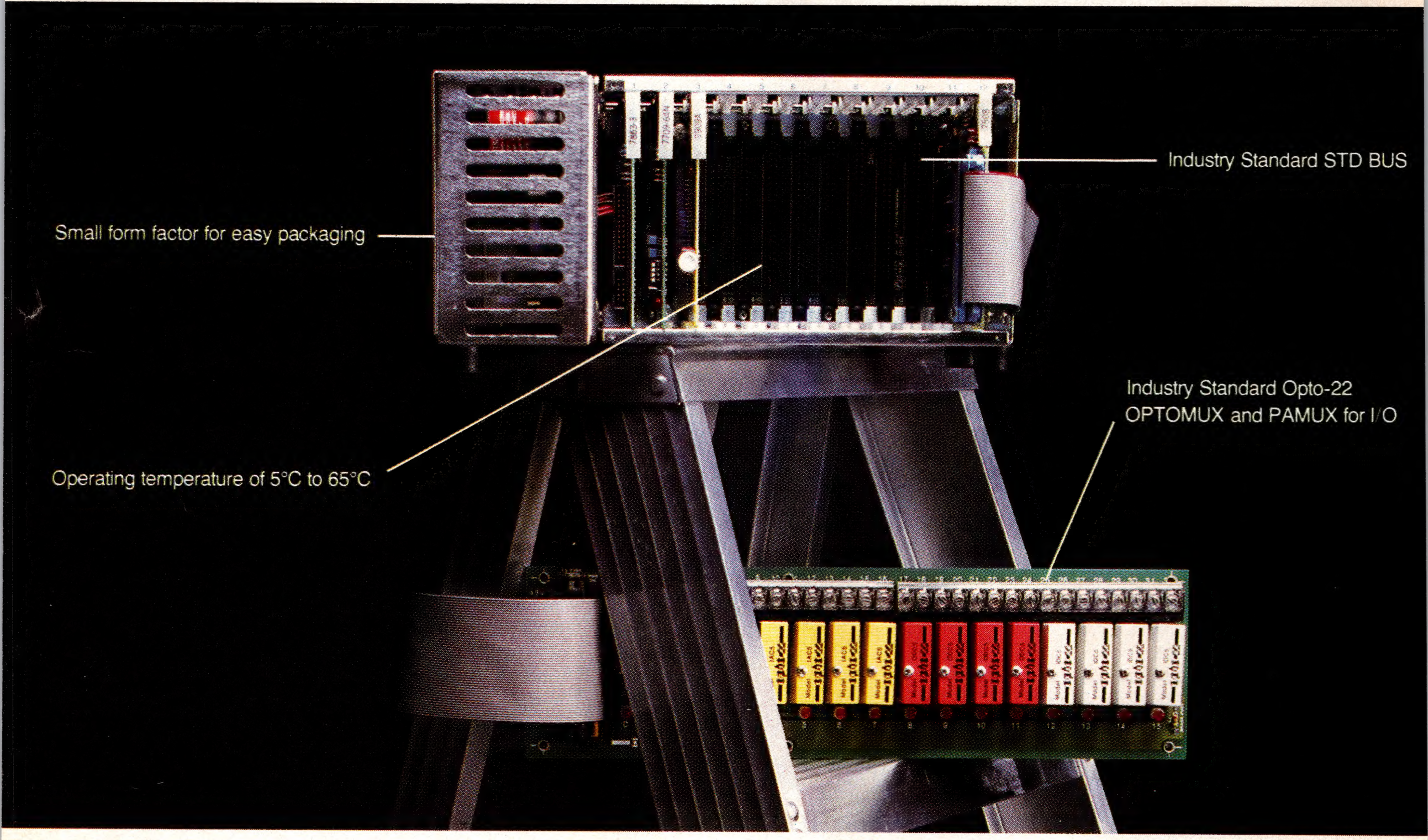
REAL-TIME MULTITASKING INDUSTRIAL CONTROL WITHOUT BEING LOCKED INTO A PROGRAMMABLE CONTROLLER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Industry Standard Opto-22 OPTOMUX and PAMUX for I/O
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- 40 PID loops

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ADGROUP INTERNATIONAL PL053

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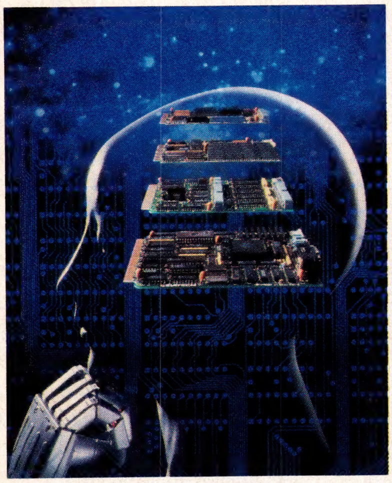
Volume 32, Number 4

EDN

February 19, 1987

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



***On the cover:** Don't let state-of-the-art technology dictate your choice of a computer bus. Instead, choose the bus that lets you get your project up and running quickly and at minimum cost. See pg 114. (Photo courtesy Ziatech)*

DESIGN FEATURES

Special Report: Industrial buses 114

You can spend a lot of time arguing the technical merits of electrical and physical bus structures, but the keys to your selection don't necessarily depend on the CPU: Instead, board size, power requirements, and ease of interfacing may be the determining factors. *—Jon Titus, Editor*

Thermal-tracking IC converts rms to dc 137

An easy-to-use IC allows you to configure circuits that accurately convert the rms value of a waveform to a dc voltage. Operating on thermal principles, the device provides much greater speed than you can obtain by using logarithmic computing techniques. Further, the IC is relatively insensitive to a waveform's crest factor.*—Jim Williams, Linear Technology Corp*

Compiler allows Ada development on an IBM PC/AT 157

You can now obtain an Ada compiler for the IBM PC/AT that provides all the features of the language and has been validated by the Department of Defense. What's more, the compiler doesn't just meet specifications; it allows you to solve real programming problems. *—Avram Tetewsky, Charles Stark Draper Laboratory Inc*

Power op amps solve deflection-yoke drive problems 171

Power op amps provide the ability to position beams in any desired position as well as the ability to retain a steady-state position. Putting both the power and signal stages in one compact package affords space/weight savings, and the lower parts count contributes to reliability.*—Granger Scofield, Apex Microtechnology Corp*

Designer's Guide to EDIF—Part 3 185

This third installment of a 4-part series shows how you can transmit your CAE/CAD tests to any system that understands the Electronic Design Interchange Format (EDIF) by translating your test patterns into that format. After you have simulated an ASIC on a workstation, for example, you can have your foundry verify your test with the foundry's own, more precise, device models.*—Esther Marx, Hart Switzer, and Mike Waters, Motorola Inc*

Continued on page 7

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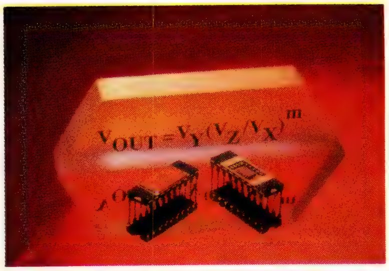
February 19, 1987



Analog multipliers have come a long way since 1953, when researchers developed a 20-lb unit that could multiply two voltages in the −50 to +50V range. Now, designers are striving to extend the 10- and 22-MHz bandwidth limits of their monolithic and hybrid versions (pg 57).

TECHNOLOGY UPDATE

Accurate, high-speed analog multipliers promise greater use of analog techniques 57

To compound the intrinsic difficulties of analog multiplication, many of today's potential multiplier applications call for higher bandwidth and lower distortion than available products can deliver. Yet the advent of much faster analog multipliers is imminent.—*Tarlton Fleming, Associate Editor*

Bridged SCSI controllers remain viable regardless of emerging embedded controllers 69

Despite being threatened with extinction by peripherals with embedded controllers, bridged, SCSI controllers allow users flexibility in I/O-subsystem design.—*Maury Wright, Regional Editor*

Artificial-intelligence techniques boost utility of CAE/CAD tools 83

Artificial intelligence has found a valuable niche in computer-aided engineering and computer-aided design. CAE/CAD tasks frequently require the use of heuristics, and the application of AI techniques can reduce uncertainty by offering software-based inferential reasoning capability.—*J D Mosley, Regional Editor*

PRODUCT UPDATE

16-bit VME Bus CPU module 99

DESIGN IDEAS

Tree structure detects multiple inputs 195
Isolation amp uses balanced modulators 196
Signal conditioner borrows power from host 200
Software routine probes TMS32010 code 200
Two-way amplifier uses few parts 204

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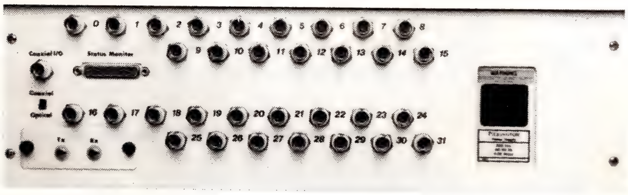

A proprietary noise suppression circuit allows you to use twisted pairs or coax, and, with the flip of a switch, fiber.

- **And you asked for serviceability.**

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EDITORIAL 53

Before you start investing in artificial intelligence, make sure your computer really needs what the software vendors hope you will buy.

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CAE & Software Development Tools 254
Test & Measurement Instruments 268

PROFESSIONAL ISSUES 287

Computer-malpractice claims pose a growing threat to software designers.—*Richard Beutel, Washington DC*

LOOKING AHEAD 297

Use of SMDs to triple in Europe by 1991 . . . Advanced ceramic products to be worth $6B+ by 1995 . . . High-resolution-CRT market to be worth $2B by 1990.

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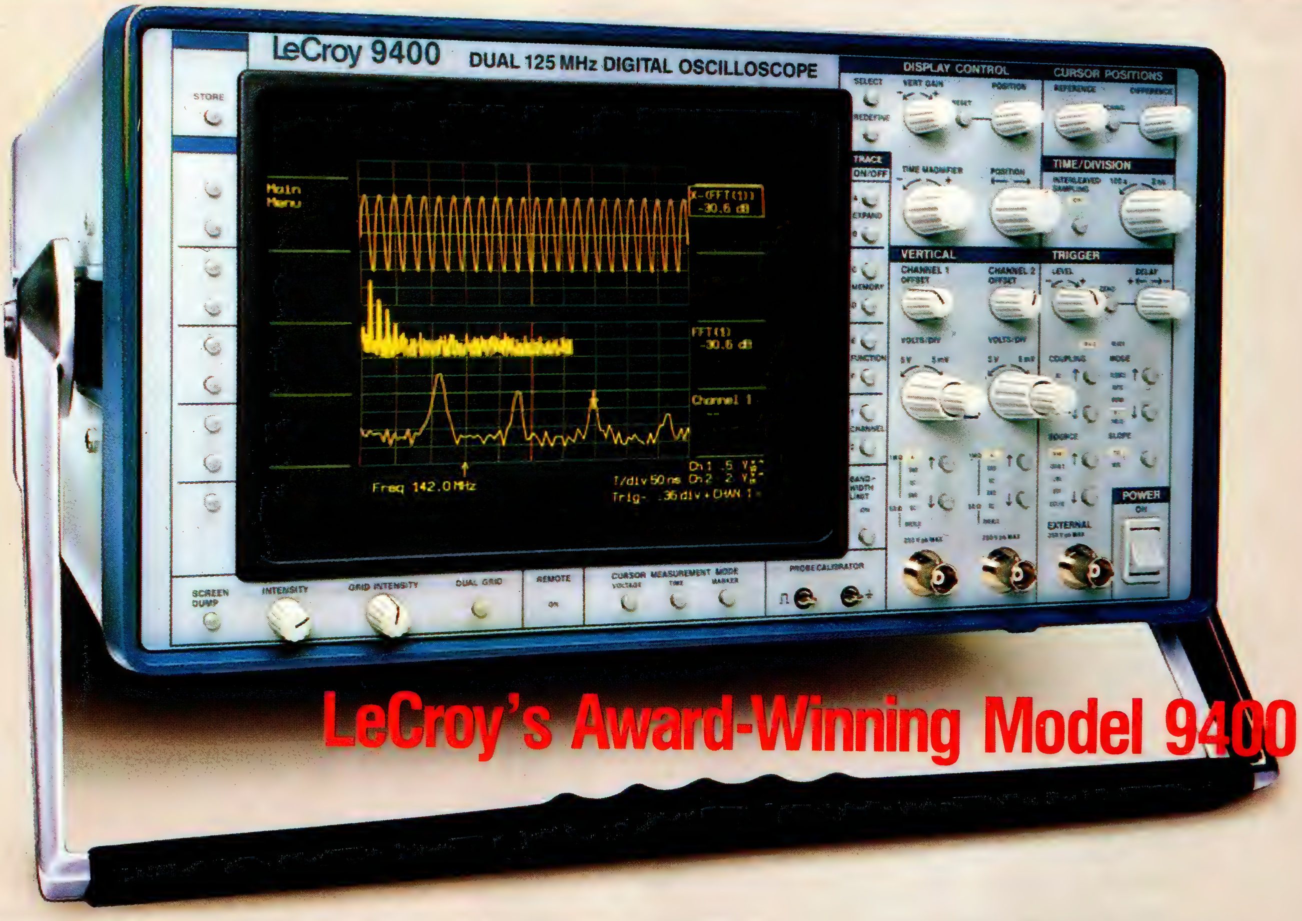
Now for the First Time in a Digital Oscilloscope...



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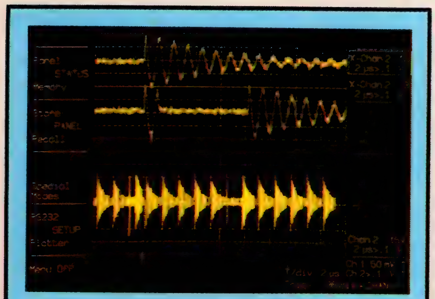
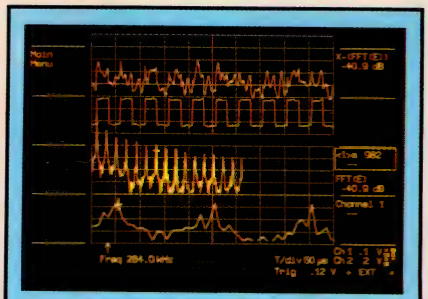
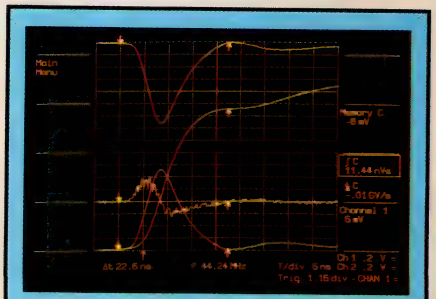


Switching transients recorded in segmented memories show contact bounce in segment number 3. Cursors can measure bounce-time-interval precisely.



Noisy R.F. Transmission Signal is averaged in time domain. Spectral content of cleaned-up signal is analyzed by FFT.



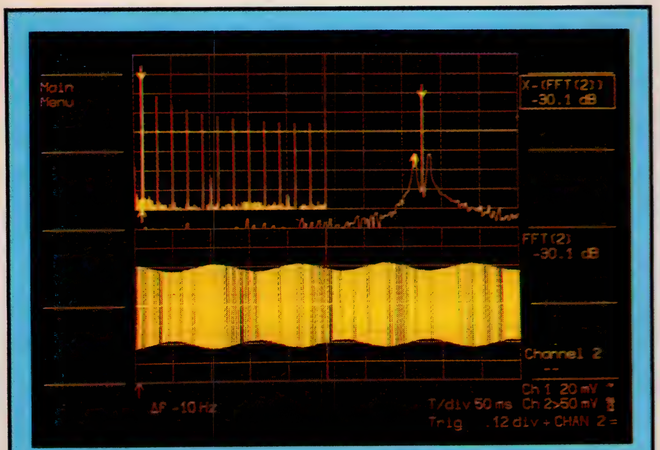
Inverted photo-diode signal is normalized then integrated for energy measurement (area under curve =11.44 nVs). Differential dC/dt is shown as well.

. . . Signal Processing in Both the Time and Frequency Domains!

UNPRECEDENTED PERFORMANCE IN A GENERAL PURPOSE DIGITAL OSCILLOSCOPE!

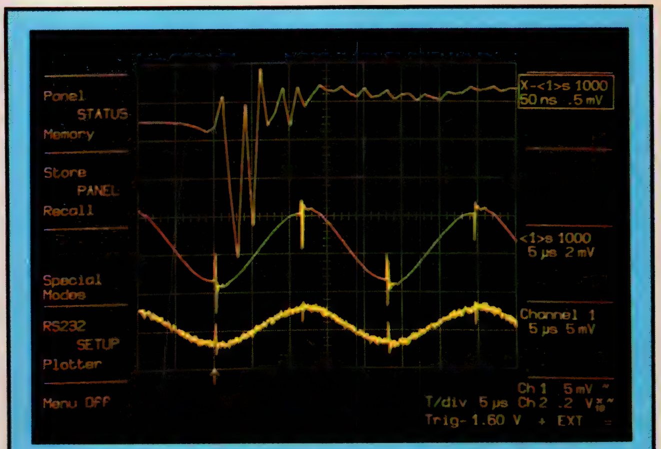
LeCroy's Model 9400 Digital Oscilloscope offers you more waveform measurement capability, more signal analysis power, longer memories and higher precision than any other digital scope. Here's how:

Start with wideband, dual-channel, simultaneous signal acquisition at 100 MS/S and a 5 GS/S random interleaved sampling rate with unmatched DC accuracy of ±1%. Add a full complement of waveform processing mathematics and then offer more memory capacity than any other scope, like 192K! Memory that can be segmented into smaller sections allowing you, for example, to store up to 250 waveforms per channel for individual analysis and comparison.



Long records give wide frequency span. Modulated audio signal, recorded over 25,000 points, shows harmonics up to 25 kHz. Expansion shows sidebands at 10 Hz and −30.1 dB. Frequency resolution is 2 Hz.

And now, with Fourier Processing, you can examine the frequency constituents of your processed time-domain data over a **WIDER** range and with **MORE** resolution than has ever been possible before with any other **portable digital scope!** The 50-25,000 point FFT variable transform size provides unequalled resolution from 1 milliHertz to 50 MHz. Large transform size FFT's yield better and faster signal-to-noise improvement than signal averaging and enable you to separate closely-spaced frequency components for detailed analysis without an external computer. Multiple, menu-selectable display options present your spectra in familiar formats, such as power spectrum, power spectral density (PSD), real and imaginary, or magnitude and phase. And, with this versatile scope, you can instantly change displays or look at the same data in different formats **without changing setups.**



Signal averaging improves dynamic range and sensitivity. Perturbation on a function generator sine wave is expanded to 500 µV/div vertically (10x) and 50 ns/div horizontally (100x) showing fine details, helpful to find cause of distortion.

And the 9400 has many more outstanding features! Unique features such as **summation** averaging up to 1,000,000 signals with offset dithering to increase the effective resolution by several bits. And, **continuous** (exponential) averaging with multiple weighting factors so you can quickly and easily minimize the effects of noise on your measurements. Do you have a time or amplitude drift problem? In its unique **EXTREMA** mode, the 9400 precisely tracks and records all extreme positive and negative values including glitches and spikes as short as 10 ns. And with its comprehensive waveform processing, the 9400 offers many powerful routines for performing signal characterization, mathematical analysis and post-processing of waveform data.

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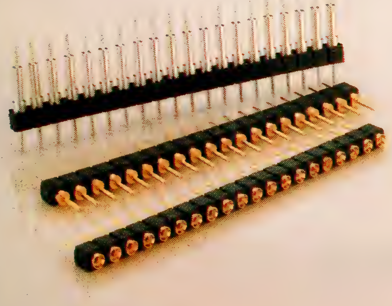

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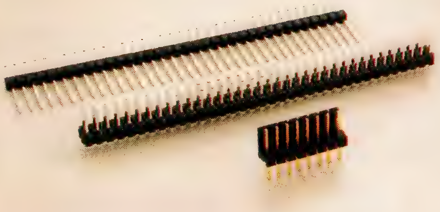
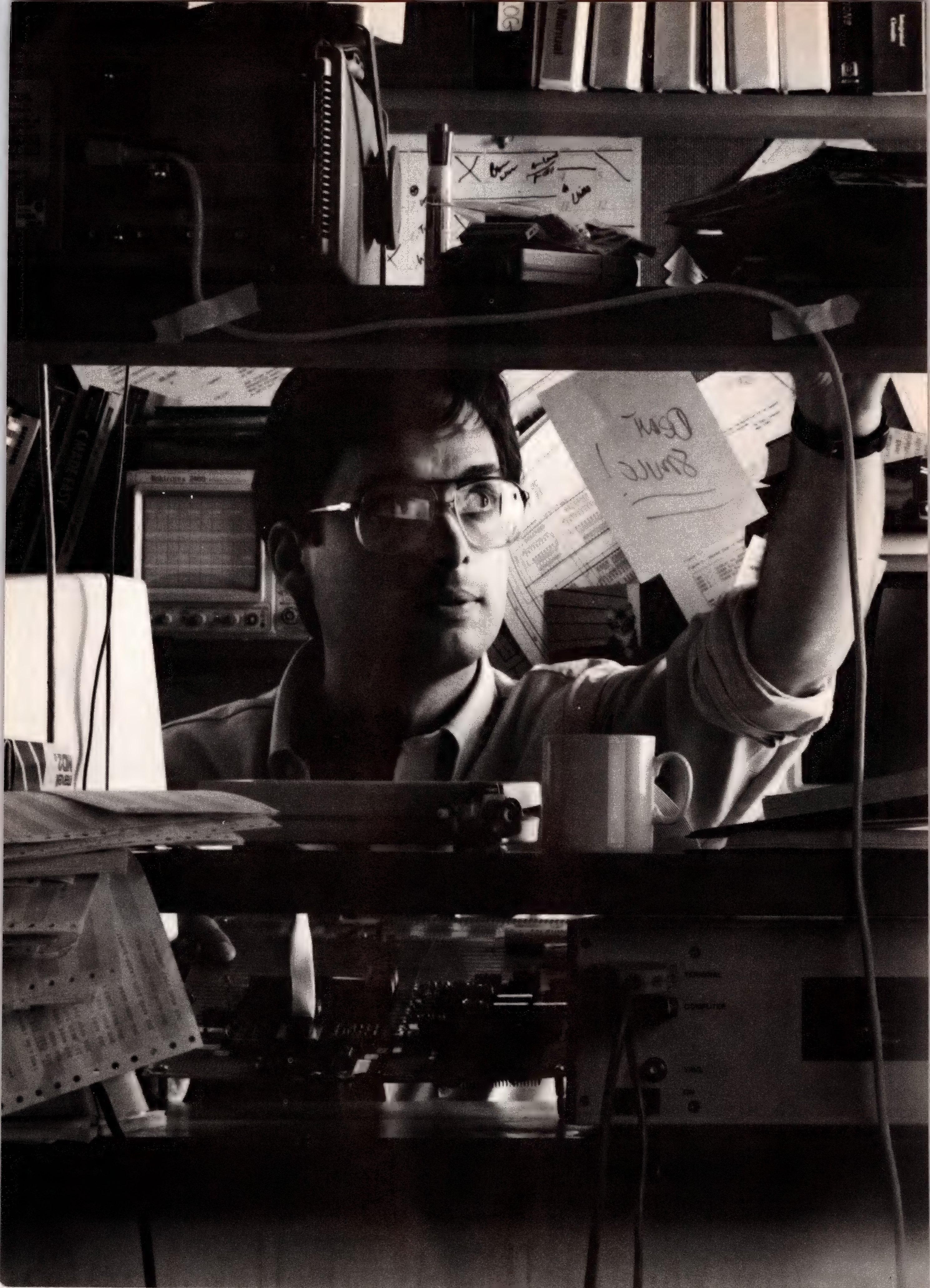


CIRCLE NO 25



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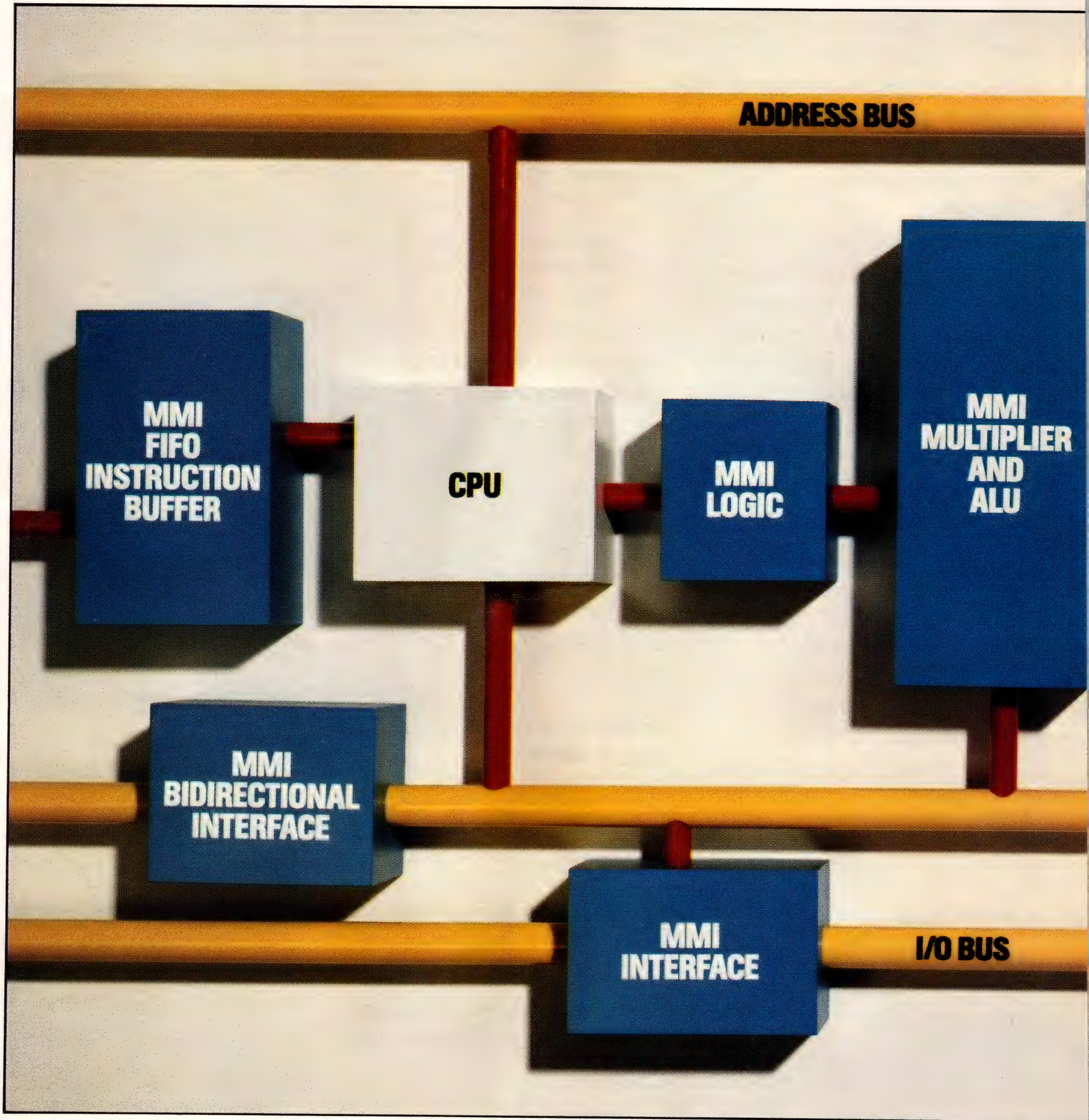

CIRCLE NO 19

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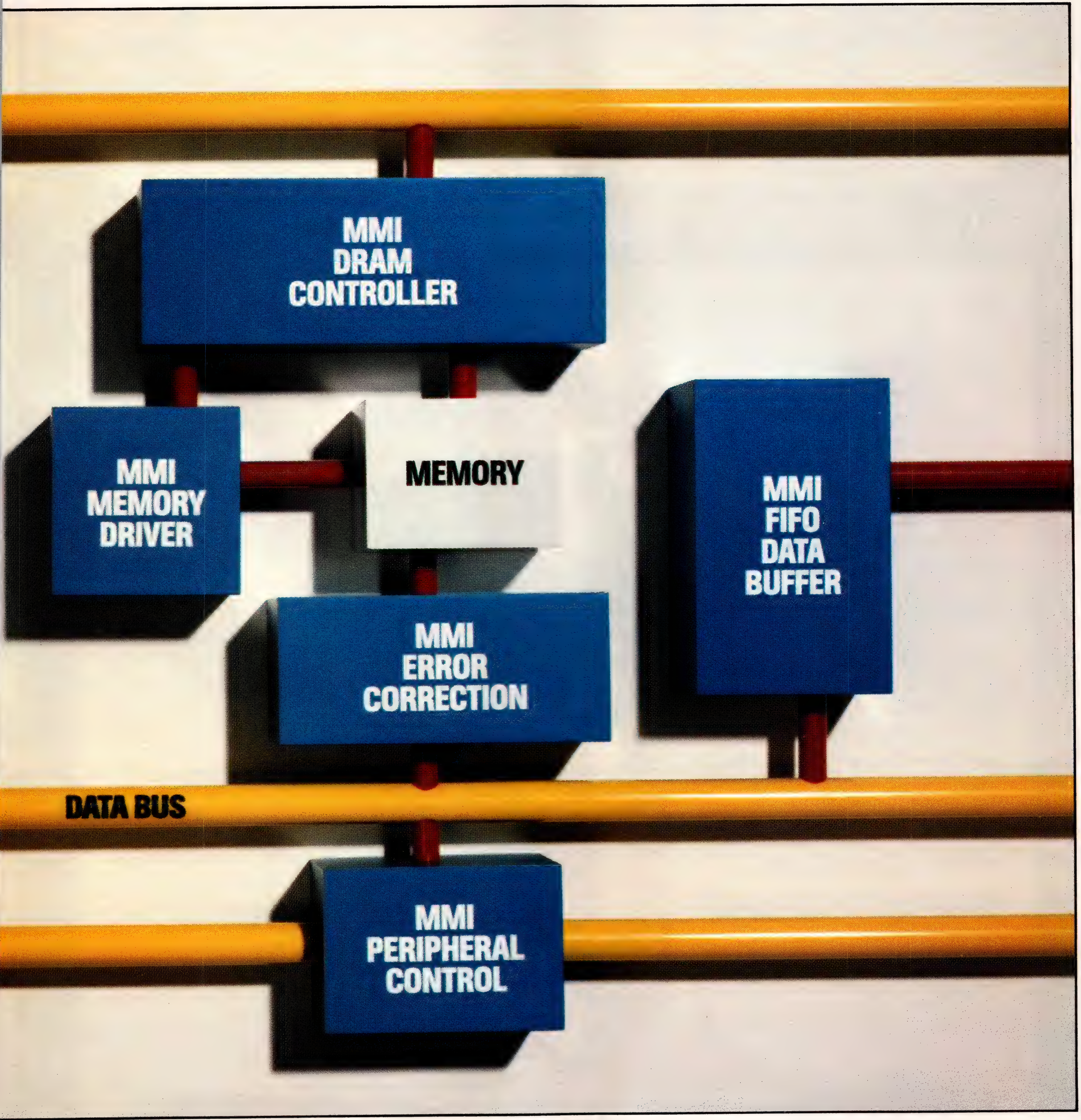

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DESIGN CONTEST

$10,000 in cash prizes – a lot to work for.

There will be 8 big winners in Zilog's Super8 Design Contest. The Super8 design judged best overall will be awarded $5,000, with $2,000 going to the Second Place winner, and $1,000 to the Third Place entry. Plus, 5 other designs will receive Honorable Mention awards of $400 each.

Super8 – a lot to work with.

Designs will be judged on their innovative use of the Super8's unmatched combination of performance and flexibility features: 20MHz speed; 600-nanosecond interrupt mode; 40 interrupt sources, with 16 vectors and 8 programmable priority levels; on-chip full duplex UART; full DMA; 3 16-bit Counter/Timers; 40 programmable I/O lines, with 2 handshake channels; 272 general purpose registers; and more.

Winners to be featured in EDN.

The winning Super8 designs will be determined by an impartial panel of judges from EDN. And EDN will announce the contest winners in the Fall of 1987.

How to enter.

First, purchase your Super8 Design Kit for $88* from your local Hall-Mark distributor between January 15 and May 15, 1987. Second, using the materials provided in your Kit, develop and debug your design. Third, send your Super8 design entry – including the appropriate documentation – to Zilog.

How to get started.

For further information, or to order your Super8 Design Kit, call your local Hall-Mark distributor. And do it today. The sooner you get going on your Super8 design, the closer you are to your share of $10,000.

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CIRCLE NO 27

NEWS BREAKS

EDITED BY JOAN MORROW

VME SINGLE-BOARD COMPUTER RUNS UNIX RELEASE 3.1

Based on AT&T's 32-bit WE 32100 chip set, the WE 321SB operates at 18 MHz and runs the first commercial version of Unix 3.1, known as Unix System V/VME. AT&T (Allentown, PA, (800) 372-2447) targets the WE 321SB for multiuser/multitasking applications. The single-board computer includes a 64-entry MMU, a 32-bit DMA controller, and a controller that supports 1M-bit dynamic RAMs. Unix release 3.1 offers several enhancements to release 3.0, such as shared libraries, a streams interface, media-independent networking support, and a device driver for Ethernet. Because the Unix System is both object-file and floppy-disk compatible with AT&T's 3B family of minicomputers, OEMs have immediate access to more than 1000 application programs for systems based on the WE 321SB. The board, which costs $3670 (100), will be available in production quantities by the end of this quarter.—Maury Wright

LOW-COST WAVEFORM GENERATOR SPECS 35-MHz, 64k-BIT PERFORMANCE

The $6995 DataSource-8600 hardware/software package from Analytic Instruments (Dallas, TX, (214) 357-3882) turns your IBM PC or compatible computer into a high-performance digital pattern generator/analyzer/recorder. It features a 35-MHz clock rate and capacity for 72 channels (each channel can be 64k bits wide). The package plugs into your computer via a half-length interface card and performs real-time data-stream comparison and error detection at frequencies ranging from 0.3 Hz to 35 MHz with 0.01% accuracy. Its unique bus interface prevents the performance deterioration associated with RS-232C and IEEE interfaces.

The WaveEdit software—a word processor for waveforms, according to the manufacturer—uses pop-up help windows, menus, and interactive color graphics to guide you through waveform design commands such as counter and clock creation, channel concatenation based on Boolean logic, and waveform inversion. You can order a free demo disk that presents all of the WaveEdit functions. The company also offers a low-performance, software-driven version of DataSource called μSource; it costs $395.—J D Mosley

LOCAL-AREA NETWORK LINKS PC-BASED CAE WORKSTATIONS

Using an Ethernet local-area network, the Dash-Net program can link PCs that run FutureNet's (Chatsworth, CA) CAE software. This package enables engineers to access host computers and to share design libraries and CAE software. For example, the system lets you transfer schematic diagrams from your PC to a central VAX.

The basic system consists of a central file server, hardware and software that you add to your PC, and a set of cables. The file server, which includes a 70M-byte hard disk and a 60M-byte tape-cartridge drive, operates under both DOS and Unix. To connect your PC to the Ethernet system, you add a communications board and driver software to the PC. Prices for the system start at $12,700.—Eva Freeman

INTELLIGENT 12-BIT A/D BOARD SAMPLES AT 156 kHz

An 80186 μP on the DAP 1200, a 156-kHz, 12-bit A/D board for the PC bus from Microstar Labs (Redmond, WA, (206) 881-4286), enables the board to perform real-time processing of your analog data. A ROM-resident real-time multitasking operating system handles hardware control, memory allocation, and data buffering. Onboard tasks communicate with each other by passing data through buffers similar to Unix pipes.

The board has 16 analog inputs, two 12-bit analog outputs, 16 digital inputs, 16 digital outputs, and a software-programmable gain amplifier. The DAP 1200/4 with a 10-MHz coprocessor and 512k bytes of RAM costs $1596. Two other versions come with an 8-MHz coprocessor and feature a 50-kHz sampling rate: The $1276 1200/2 has 128k bytes of RAM, and the $1436 1200/3 provides 512k bytes.—Margery S Conner

CHIP USES VOICE-COMPRESSION ALGORITHM TO DOUBLE T1 CAPACITY

The DS2167 combines a digital signal processor (DSP) and an algorithm known as Adaptive Differential Pulse Code Modulation (ADPCM) on a single chip. The result is a voice-transmission rate of 32k bps, which effectively doubles the capacity of 64k-bps full-duplex telephone transmission links. Developed by Dallas Semiconductor (Dallas, TX, (214) 450-0400), this IC conforms to the latest CCITT standards. You can expand a 24-voice-channel T1 line to accommodate 48 channels by splicing one DS2167 chip per voice channel into each end of the T1 line, or you can use the DS2167 to integrate voice and data services. This 24-pin CMOS IC consumes less than 150 mW of power and costs $39 (1000).—J D Mosley

GALLIUM ARSENIDE SEMICUSTOM SERVICES AVAILABLE FROM HARRIS

Harris Microwave Semiconductor (Milpitas, CA, (408) 262-2222) offers a range of GaAs digital semicustom services, including a standard-cell library and front-to-back CAE support. The library of 35 cells is a collection of basic logic functions implemented with buffered FET logic and a 2-level metal interconnect. It is flexible enough to define new cells if needed. The Unix-based CAE system can be used on Harris MCX-3, MassComp (5400, 5500, 5600), MicroVax/GPX, Sun 3/160, and Apollo (DN660, Turbo 570) workstations. Harris supplies you with a CAE user's manual and a cell-library manual, including data sheets on each cell. Upon receipt of validated test vectors, Harris will test the devices using its own customized equipment. Packaging options include 32- and 48-pin hermetic flat packs or chip carriers of your own preference. A typical dedicated program, including testing and packaging, costs approximately $60,000; you receive 25 samples.—Dave Pryce

IBM PC-BASED SIMULATOR SUPPORTS 68000/10 SOFTWARE DEVELOPMENT

Big Bang Software Inc (Panama City, FL, (904) 784-3393) now offers a simulator/debugger for Motorola 68000/680010 μPs. The simulator runs on IBM PCs and compatible systems and costs $285. With the software package, you can display or disassemble hex files of Motorola S-Records. The program controls simulated execution in fast and single-step modes, and you can view registers, flags, and μP memory after each instruction executes. The program also includes load, dump, and breakpoint facilities. To run the program, you need a personal computer with DOS 2.0 or higher and 256k bytes of memory.—Maury Wright

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NEWS BREAKS: INTERNATIONAL

VME BUS VIDEO BOARD FEATURES A FRAME GRABBER AND FRAME STORE

The Virtuoso video card from Primagraphics (Melbourn, UK, TLX 817932) incorporates a frame grabber and a frame store on one double-Eurocard VME Bus board; thus, data transfers between the frame grabber and frame store don't load the VME Bus. Priced at less than £2000, the video card features an 8-bit digitizer, 512k bytes of frame-store memory, and a color look-up table that provides 256 colors from a palette of 16 million colors. The digitizer operates at sample rates of 15 or 13.5 MHz, suiting it for use in 625- or 525-line video systems. The frame store is dual ported to the digitizer and to the VME Bus. It has a separate overlay plane that allows you to mix video and graphics images. Video input and output to the board is via standard 75Ω, 1V p-p video signals.—Peter Harold

JAPANESE COMPANIES SHIFT TO 1M-BIT DYNAMIC-RAM PRODUCTION

In response to increased demand for larger memory devices, Japanese semiconductor manufacturers are beginning to slow down production of 256k-bit dynamic RAMs and increase the supply of 1M-bit dynamic RAMs. Two of the leading semiconductor vendors—Toshiba Corp and Hitachi—have already increased production; Mitsubishi Electric, Nippon Electric, and Fujitsu are expected to follow this trend soon.

Toshiba, the leading manufacturer of 1M-bit dynamic RAMs, will raise its monthly production of these devices from 500,000 pieces to 1 million next month. Hitachi claims it will reach the same level during the fall.—Joan Morrow

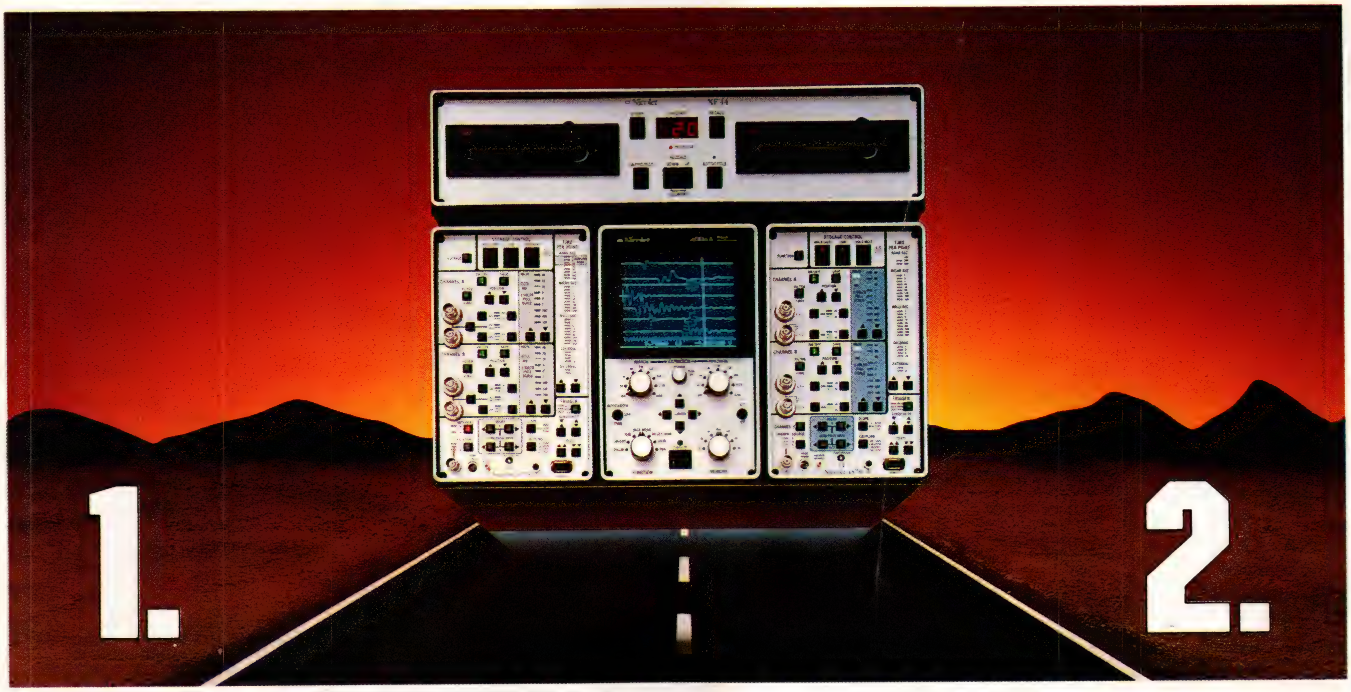
LOGIC ANALYZER IS BUILT AROUND IBM PC/AT-COMPATIBLE COMPUTER

The PLA-286 logic analyzer from Kontron Messtechnik GmbH (Eching, West Germany, TLX 526719) uses the company's ruggedized PC/AT-compatible computer, which will accept plug-in boards to provide as many as 16 100-MHz timing channels and 96 20-MHz timing/state channels. You can use the full complement of timing and state channels together. The timing analyzer allows you to qualify trigger words with time windows and to search for trigger signals that are longer or shorter than a defined period. The 100-MHz channels have a trace-memory depth of 8k words, and the 20-MHz channels have a memory depth of 4k words. The analyzer, which also provides an IBM PC/AT-compatible environment for running commercial software under the MS-DOS operating system, costs approximately DM 15,000 to DM 31,000 depending on configuration.—Peter Harold

UNIX WORKSTATIONS SELL FOR LESS THAN $3000

Two Unix workstations, the Model 50UX-10 and -20 from Hitachi Ltd, are 32-bit machines built around Motorola's MC68010 microprocessor. They feature 1M byte of main memory, which is expandable to 4M bytes. The Model 50UX-10, which comes with a 720×520-dot display, sells for ¥398,000 ($2488); the 50UX-20, incorporating a 1120×780-dot display, is priced at $3113.—Joan Morrow

THE FIRST NAME IN DIGITAL SCOPES



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With sweep speeds from days to nanoseconds and resolution up to 15 bits, the 4094 digital 'scope can capture the most elusive signals. Every plug-in has 16K of memory, viewable trigger set-up and independent pre- or post-trigger delay on each channel. Signal averaging is standard and our latest 10 MHz/12-bit plug-in even offers real time manipulation of the incoming signals. With two plug-ins the 4094 can record four channels simultaneously. Or even monitor two slow signals and capture high speed glitches at the same time. All under computer control or via manual operation: whatever your application demands.

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DC-1500 MHz	±0.3	0.6	0.8	1.3	1.5

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2	●	●	●	●
3	●	●■	●	●
4	●	●	●	●
5	●	●	●	●
6	●	●■	●	●
7	●	●	●	●
8	●	●	●	●
9	●	●	●	●
10	●	●■	●	●
12	●	●	●	●
15	●	●■	●	●
20	●	●■	●	●
30	●	●	●	●
40	●	●	●	●

PRICING (1-49 qty.): CAT (BNC)..\$11.95, SAT (SMA)..\$14.95
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C 92 REV. B

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SPECIFICATIONS for
PSW 1111 (SPST) **and PSW 1211** (SPDT)
ZMSW 1111 and ZMSW 1211

FREQUENCY RANGE	10-2500 MHz
INSERTION LOSS	
10-2000 MHz	1.7 dB max.
2000-2500 MHz	2.7 dB max.
ISOLATION	
10-500 MHz	40 dB min.
500-1000 MHz	30 dB min.
1000-2000 MHz	25 dB min.
2000-2500 MHz	20 dB min.
SWR	1.5 max. ("on" state)
SWITCHING SPEED	1 μsec. (max.)
MAXIMUM RF INPUT	+20 dBm
CONTROL	+5 V (5 mA max.)
OPERATING TEMPERATURE	−54°C to +100°C
STORAGE TEMPERATURE	−54°C to +100°C

PRICE (6-24)		(1-4)	
PSW 1111	$29.95	ZMSW 1111	$59.95
PSW 1211	$29.95	ZMSW 1211	$59.95

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C80 REV. B

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The HP DesignCenter offers integrated CAE/CAD software tools that accelerate the design process from idea to test. These tools, which run on the HP 9000 Series 300 technical workstations, improve productivity and communication throughout the product development process. So engineers can design faster and get products to market quickly.

Analog and digital design on one system

Both digital *and* analog designers can use the same HP design capture system, helping you to maximize return from your CAE/CAD investment. The system offers a number of features that help speed design, including a consistent environment of component libraries and schematics; hierarchical design entry; integrated documentation; on-line electrical rule checking; automatic component selection; and links between external design tools and design capture.

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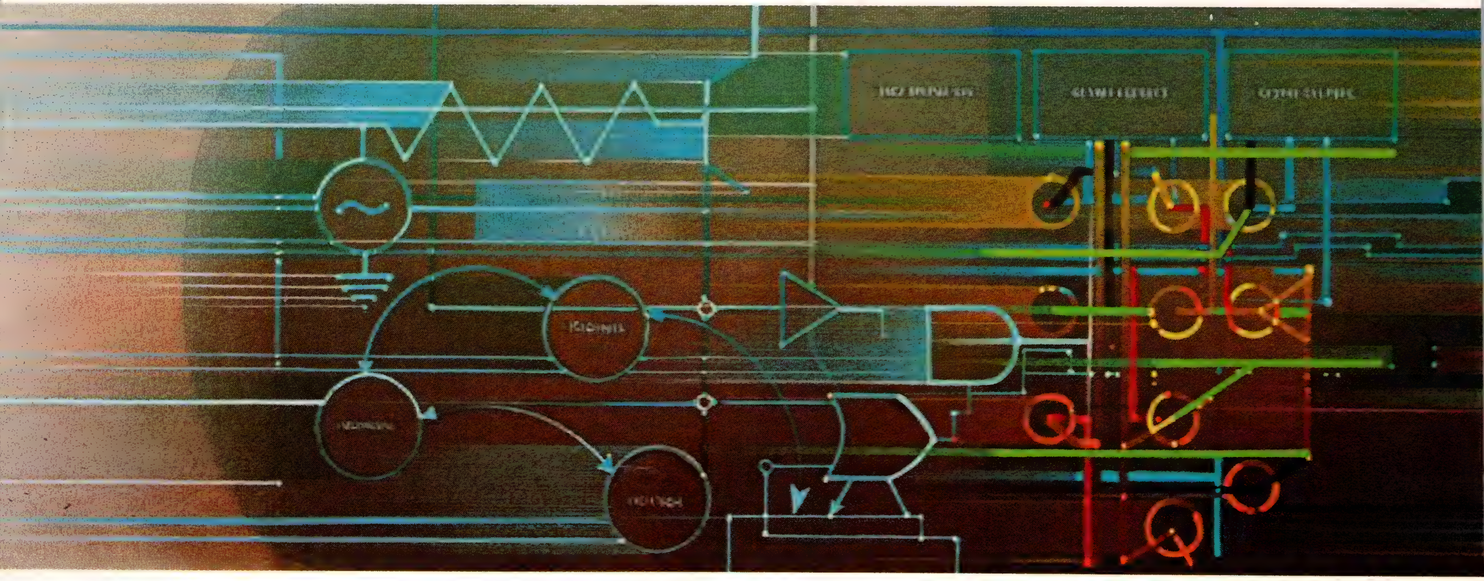
You get HP computer-aided software engineering. And some of the most advanced hardware and software integration tools available, including real-time emulation for over 40 processors. These tools let engineers tap the power of HP's microprocessor development environment to speed product development.

There's even a link to design capture from microprocessor system development so engineers can transfer programs directly to simulation, reducing both simulation setup time and the possibility of manual-entry errors.

Advanced PCB design tools for a head start in manufacturing

HP's automated printed circuit design system helps

Accelerate your product from idea to design and



Go from engineering design ▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷

turn engineering ideas into finished printed-circuit boards quickly. And gives you the assurance that boards will match the approved design from engineering and be practical to manufacture.

You get a link from schematic capture to PCB design for highest design integrity, and system features that optimize designs for your actual manufacturing environment. The result is reduced manufacturing costs, higher yield, and improved reliability.

You can also transfer netlist and part information from PCB design to HP's board test system, ending manual-entry hassles and errors.

HP DesignCenter: our commitment to CAE/CAD

HP's CAE/CAD tools are part of HP DesignCenter . . . a powerful product development environment that unites the activities of electronic, mechanical, and software engineers through integrated systems, software, and support.

For all the facts, call your local HP sales office listed in the telephone directory white pages. Or call 1-800-447-3282 (in Colorado call 590-3340 collect) for free literature on our CAE/CAD solutions.

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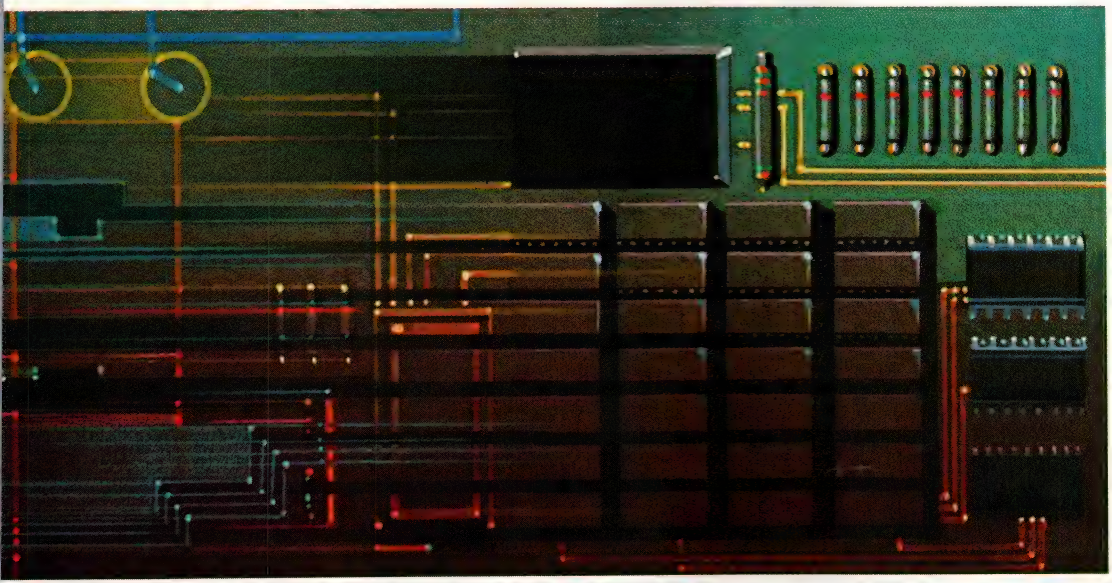
What if...

development test.



▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷▷ to finished product faster

DS15611

CIRCLE NO 50

GE/RCA HC: *Your clear path*

into the world of CMOS.

Only GE/RCA has the broad line, unique parts and 25 years of CMOS experience to support you every step of the way.

Your venture into the world of high-speed CMOS can be very rewarding—if you travel with the right CMOS partner.

A logical first step.

We have been the leader in CMOS logic for more than two decades.

We pioneered with the 4000 series and followed with high-speed CMOS and ACL.

Today, we have more than 270 high-speed CMOS devices. And that number is growing fast, because every time we make a new HC device (and we have the industry's broadest line), we make the corresponding part in HCT, too.

A design engineer's dream.

This broad line includes quite a few unique parts (for a sample, see the box below). And we have extensive experience in High-Rel, ASICs, memories and microprocessors, so we can help you get the most possible from this outstanding technology.

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There's more to good CMOS than good design. We have a track record of delivering competitively-priced parts on time. And we've invested millions of dollars to provide the production capacity and leading-edge technology you need.

Add to this a record for reliability that has truly withstood the test of time (after all, we invented CMOS), and you'll see why so many people have started successful journeys into CMOS with GE/RCA at their side.

Take a big step in the right direction, and call toll-free 800-443-7364, ext. 15. Or contact your local sales office or distributor.

Our unique high-speed CMOS analog switches are among the highest frequency, lowest distortion devices available today.

HC/HCT4016, 4066, 4316

- Low Ron, 125 ohm typically (4016, 4316), 25 ohm typically (4066), Vcc=4.5V.
- Frequency response of -3db down @ 180 MHz (4016, 4316), -3db down @ 200 MHz (4066), both driving a 75 ohm load.
- Low distortion.
- Maximum control switching frequency to 35 MHz.
- Low "OFF" leakage current.
- Applications: Instrumentation, Direct Current to 50 MHz Switching Systems, Cable TV, Workstations.

HC/HCT4051, 4052, 4053, 4351, 4352, 4353

- Wide analog input voltage range: ±5.5V max.
- Low "ON" resistance: 70 ohm typ (Vcc-Vee = 4.5V), 40 ohm typ (Vcc-Vee = 9V).
- Low crosstalk between switches.
- Fast switching and propagation speeds.
- "Break-before-make" switching.
- Applications: Audio and Video Switches, Synch. Detection, Video Mixing, RF Frequency Switching, Data Multiplexing, Data Conversion, Data Transmission.

Our Phase-Locked Loop devices offer greater speed and linearity than any other CMOS PLL's...plus low power consumption.

HC/HCT4046A

- Operating frequency range up to 17 MHz (fc) at Vcc=4.5V.
- Built-in op amps for excellent linearity.
- Op-amp buffered demodulated output.
- 3 phase comparators to choose from.
- Applications: FM Modulation/Demodulation, Frequency Synthesis, Frequency Multiplexing, Voltage to Frequency/Frequency to Voltage Conversion, Servo Control Systems, Data Synchronization, Manchester Coding/Decoding.

HC/HCT7046

- Operating frequency range up to 17 MHz (fc) at Vcc=4.5V.
- Built-in op amps for excellent linearity.
- Op-amp buffered demodulated output.
- A pin which indicates lock detect.
- 2 phase comparators to choose from.
- Applications: FM Modulation/Demodulation, Frequency Synthesis, Frequency Multiplexing, Voltage to Frequency/Frequency to Voltage Conversion, Servo Control Systems, Data Synchronization, Manchester Coding/Decoding.

GE RCA

SIGNALS & NOISE

Battery suppliers don't serve customers

Dear Editor:

The Special Report on backup batteries (EDN, October 30, 1986, pg 132) is very timely. Mr Small's caveats regarding lithium batteries are well taken, but he missed the most important one. From my experience during the past year, the service from battery suppliers, their representatives, and their distributors is really lacking in comparison with the service from suppliers of other electronic components. For this reason, I expect engineers to favor EEPROMs over CMOS static RAMs.

Battery suppliers don't understand electronic-component distribution: For distributors, they use specialists in batteries. The problem with this arrangement is that you can't buy the batteries from the same distributors that sell you other parts. These special distributors charge a lot for batteries in low volume, such as hundreds.

For some standard items in its catalog, Panasonic, for example, requires a minimum purchase of 400 pieces. And the leadtime is 10 to 12 weeks. To top it off, the order is nonreturnable. Rayovac offers the same part, but it doesn't answer mailed inquiries, and its distributors don't call back with answers to quote requests.

I could go on, but your readers will get my message. My caveat is that designers will spend more time on battery-sourcing problems than on the technical aspects of their backup-battery designs. I did, out of necessity. In frustration, I even wrote to the head of Panasonic's battery division. But that was a waste of time.

Good luck to all potential lithium-battery users.

Sincerely yours,
Edward W Rummel
Robin Baker Associates Inc
Short Hills, NJ

Computers can't replace good writers

Dear Editor:

Thank you for Rick Nelson's editorial "Don't yield to computer-aided thinking," which appeared in the October 16, 1986, issue of EDN (pg 53).

The very idea that the nuances of grammar, personal expression, and writing style can be stored on a floppy disk for instant retrieval is ludicrous, and the connotation that an inept writer can become proficient simply by processing mediocre copy through an electronic device is

Text continued on pg 34

QUICK.

Name the company that makes the fastest high-density CMOS and bipolar PROMs on the market.

(You're probably wrong. See page 182.)

The Personal EPROM Programmer . . .

MODEL 9000
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- Adds (E)EPROM programming to your PC based development system
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BUILDING BLOCKS.

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SPRAGUE POWER OP AMPS SIMPLIFY DESIGNS, BY DESIGN.

Six new Sprague power operational amplifiers meet the growing need for monolithic linear interface drivers by providing a low-component-count solution to high-current design challenges. The new devices are capable of driving loads up to ±3.5 A and ±20 V. These single and dual-channel power op amps are universal building blocks that merge the versatility of small-signal op amps with the brute force capability of power drivers. Comprehensive protective features are provided on-chip. Recommended applications include use with servo systems, dc motors, single and multi-phase ac motors, disc drives, audio systems, CRT deflectors, and voltage regulators. *Sprague Electric Company, a Penn Central unit,* World Headquarters, Lexington, MA. For Brochure WR-206 and applications information on Power Operational Amplifiers, write to Technical Literature Service, Sprague Electric Company, 41 Hampden Road, P.O. Box 9102, Mansfield, MA 02048-9102. For applications assistance, call Ron Lutz at (617) 853-5000.

SPRAGUE
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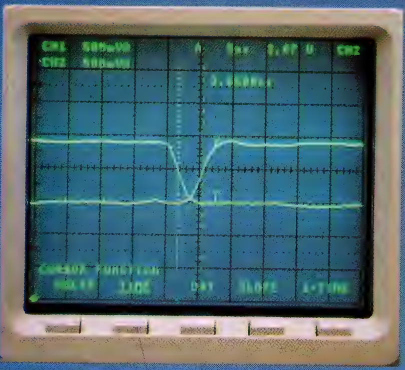
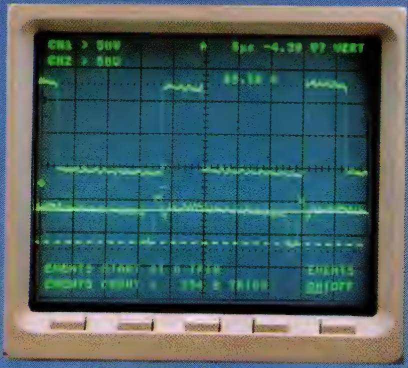
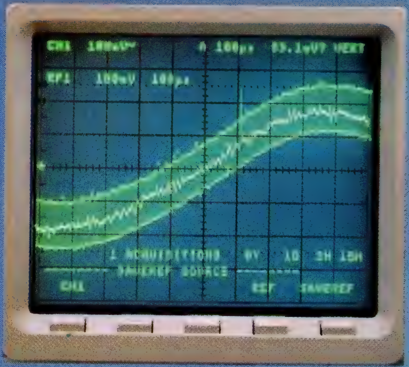
CIRCLE NO 29



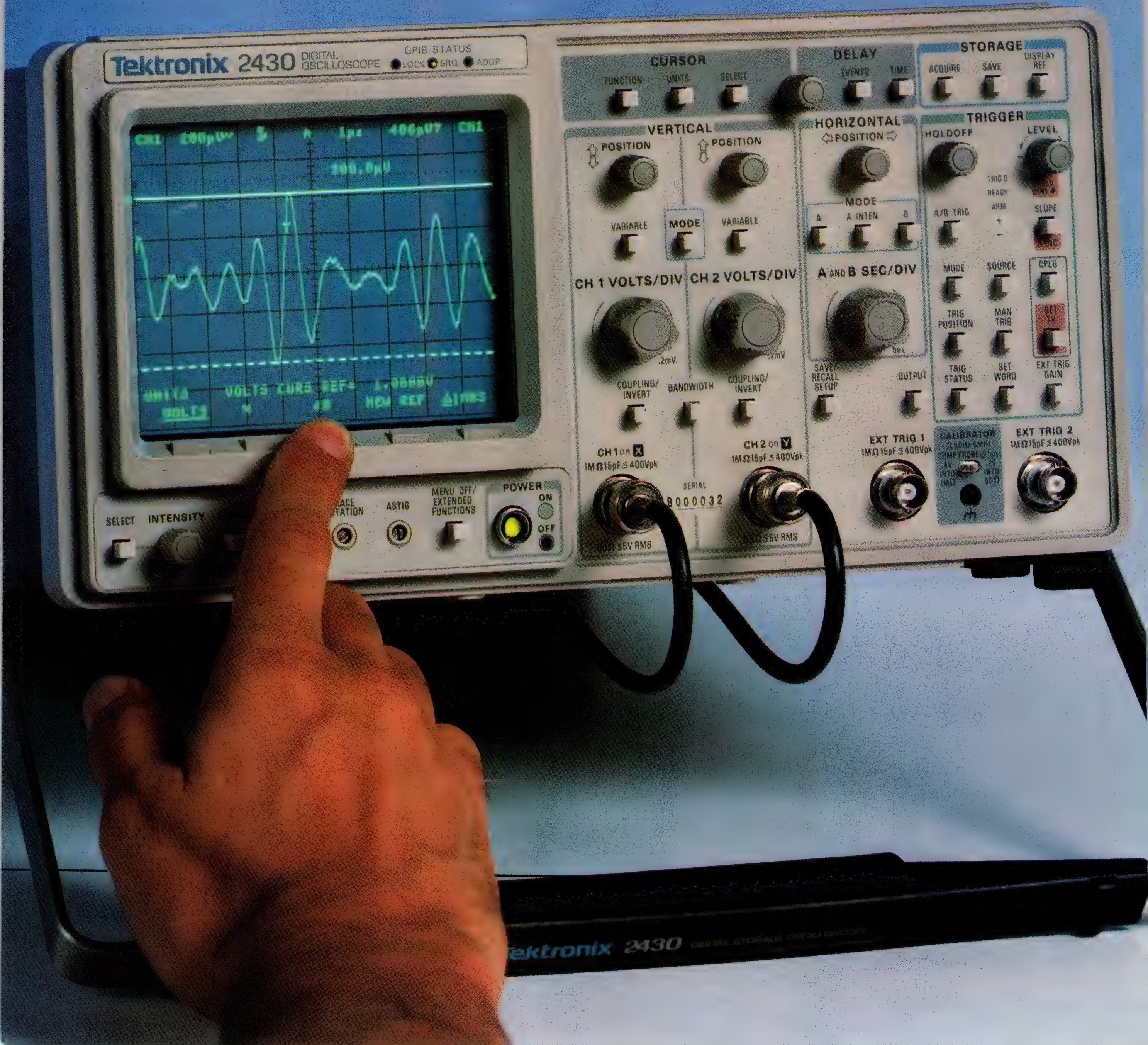
With its 150 MHz bandwidth, 5 ns/div maximum sweep speed and 2-channel simultaneous acquisition, the 2430 displays TTL and ECL signals for risetime and coincidence measurements. (Above) The scope is used in 50 ohm input termination with a 500 ohm probe for an accurate measurement of propagation delay through an ECL inverter.



How long does it take a transformer to reach operating voltage? Using DELAY BY EVENTS, the 2430 lets you select the 254th (or any other) switching event of the pulse-width modulator in a high-efficiency power supply.



A new Tek patented feature, SAVE ON DELTA instructs the 2430 to compare incoming acquisitions against a user defined reference and save it in the event of a difference. You can catch intermittent failures automatically and implement automatic tests with improved repeatability.



TEK'S NEW 2430.
THE REVOLUTIONARY DIGITAL SCOPE YOU ALREADY KNOW HOW TO USE.

We've expanded the best features of our familiar, industry-standard 2400 Series in a new portable scope that sets some standards of its own. Start with a 150 MHz bandwidth and a 100 MS/sec digitizing rate plus dual channel simultaneous acquisition. It's a powerful combination that enables you to digitize, view and store fast and complex signals.

Add 8-bit vertical resolution, 1K record length per channel and a 0.01% crystal-controlled timebase for making accurate measurements with ease.

The result: an advanced measurement package with many sophisticated capabilities built in especially for solving tough product design problems.

All-purpose high performance at its affordable best! The 2430 not only handily meets your general purpose measurement needs, it gives you a lot more. With digital capabilities come powerful waveform manipulation functions ranging from waveform multiplication to high-resolution averaging.

It is also fully programmable via the GPIB. Complete talk/listen capabilities extend the scope's power and make it a valuable systems component for making automatic measurements. You can develop test procedures that can be used later on the manufacturing floor. Plus, the time-consuming task of waveform characterization, analysis and logging is simplified.

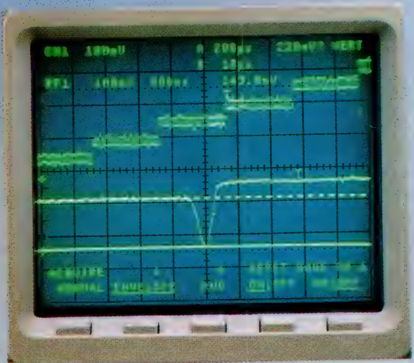
In addition, the 2430 can store waveforms and front panel setups in nonvolatile memory.

The 2430 exhibits unusual power as a troubleshooting tool. The patented peak detection circuit lets you capture glitches as narrow as 2 ns at any sweep speed with confidence—a level of performance available until now in only the most expensive instruments.

The 2430's envelope mode, which automatically captures and updates signal minimums and maximums, allows you to conveniently study signal variations such as jitter, drift and stability. It also monitors signal excursions outside user-defined limits.

Plus, a broad range of pretrigger selections available in all modes makes it possible to examine conditions leading up to an event. The crystal-controlled timebase allows you to delay by time and/or events for precise timing measurements in complex triggering modes. You can even trigger on digital words.

Best of all, we've kept the 2430 easy to use. From the simple, one-level menus for standard functions to the comfortable grouping of the front panel controls, the 2430 was designed to drive like the scopes you already use.



DAC glitches won't escape you with the 2430's enhanced ENVELOPE function. The peak-detecting ENVELOPE mode enables you to catch events as narrow as 2 ns, even with a single acquisition, at any sweep speed.

With full pr
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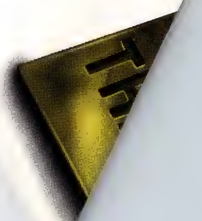

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CIRCLE NO 30

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an insult to the writing profession.

Sincerely yours,
Thomas J Fournier
Technical Writer
The DeVilbiss Co
Ann Arbor, MI

Readers' comments

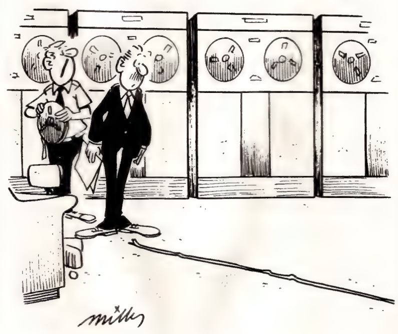
- *On writing*

"Deborah Asbrand's article on writing ["Learning to write well helps engineers overcome anxieties about communicating," EDN, July 24, 1986, pg 263] is a much better piece of writing than most other articles about writing that I have read. However, the article makes no reference to the possibility that most engineers lack the experience of good reading, which might better be found in a liberal arts curriculum."—*A M, Bellevue, WA*

Writing is simply an extension of thought process; writing per se can't improve (and especially can't be taught) if the engineer doesn't think clearly."—*B A, Randolph, NJ*

- *Misnomers*

"While you are (correctly) flinging rocks at those who misapply terminology [see "Misapplication specific," EDN, May 15, 1986, pg 47], I suggest that you fling a few also at those who use the term 'system' for two simple components or use 'media' to refer to a single recording medium."—*M A, McLean, VA*



"HE'S GOT THE INFORMATION YOU WANT . . . YOU SHOULDN'T HAVE ANY TROUBLE FINDING HIM."

Battery information

Please note the following corrections to the Special Report on backup batteries (EDN, October 30, 1986, pg 132). First, the article incorrectly states that " . . . because of potential problems from polluting chemicals, possible explosions, and other handling problems, you cannot get UL recognition for thionylchloride lithium batteries." In fact, Union Carbide's Battery Products Div, the predecessor of the present Eveready Battery Co, was granted UL component recognition on a thionylchloride lithium battery on March 16, 1983. This recognition is still in force.

Further, the phone number listed in the article for Eagle-Picher Industries Inc (pg 148) is incorrect. The correct number is (417) 776-2256.

YOUR TURN

EDN's Signals and Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

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STOP WISHING FOR THE IMPOSSIBLE IN DIGITAL ANALYSIS!

1
Complex, state-driven triggering at 200 MHz.

2
Symbolic, real-time software debugging.

3
Simultaneous integration of multiple microprocessors.

4
100 + channels of acquisition at 2 GHz.

5
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6
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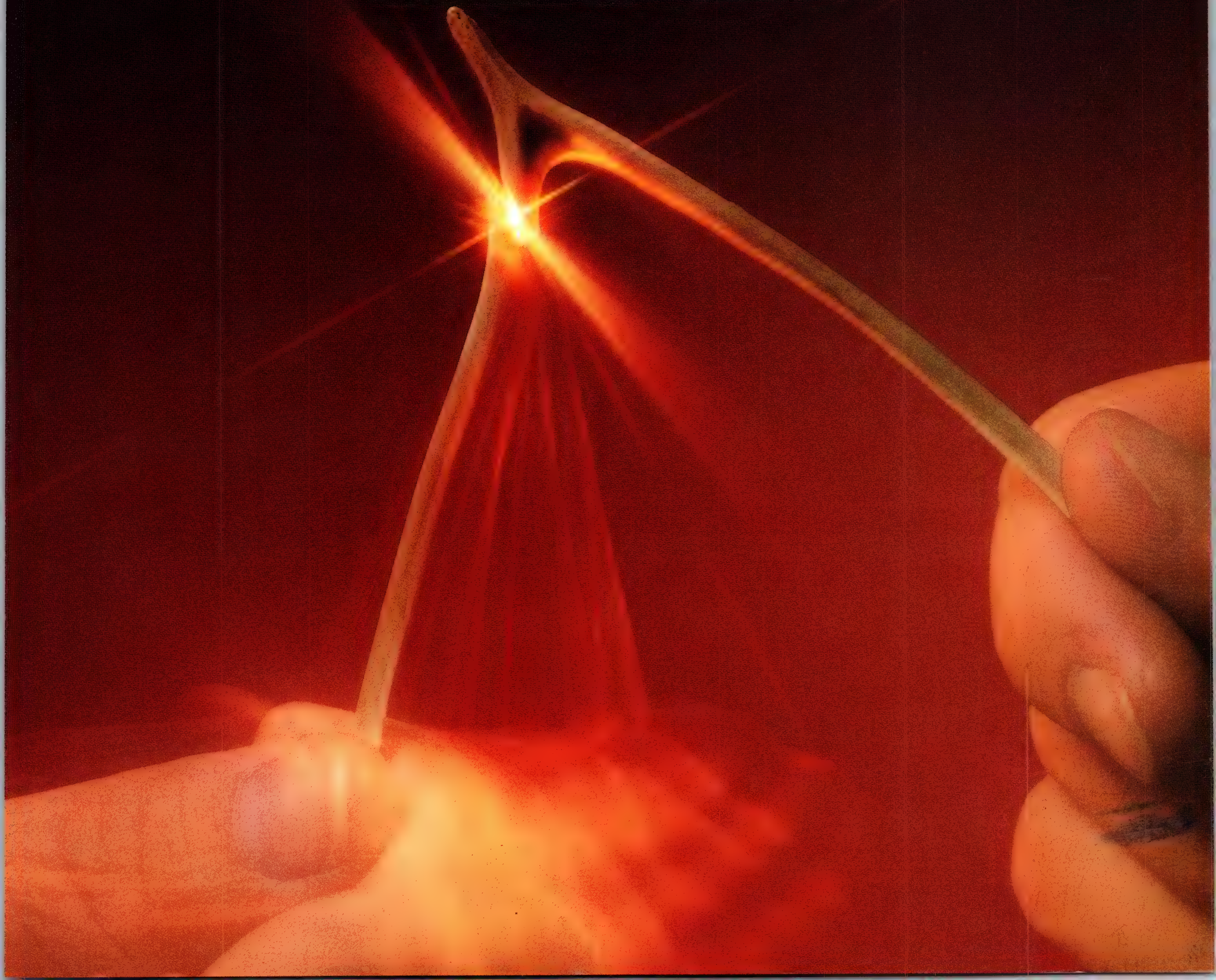
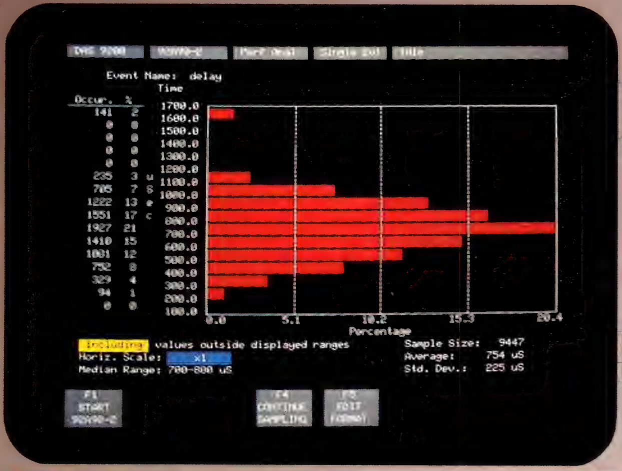
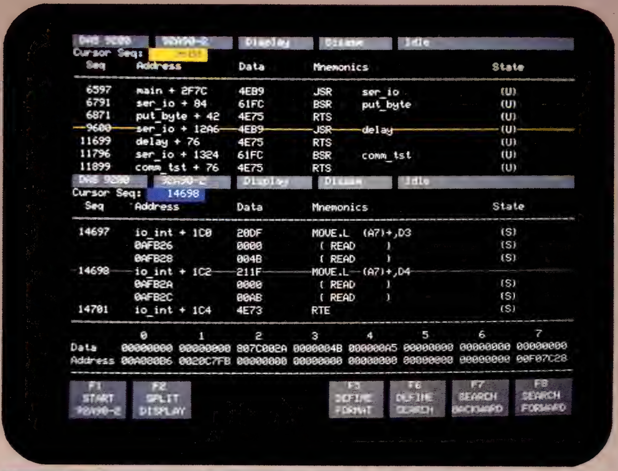


INTRODUCING THE DAS9200: NOW TEK MAKES THE IMPOSSIBLE LOOK EASY.



```
Event Name:  delay
                Time
Occur.   %
   141   2     1700.0
     0   0     1600.0
     0   0     1500.0
     0   0     1400.0
     0   0     1300.0
     0   0     1200.0
   235   3  u  1100.0
   705   7  s  1000.0
  1222  13  e   900.0
  1551  17  c   800.0
  1927  21      700.0
  1410  15      600.0
  1001  12      500.0
   752   8      400.0
   329   4      300.0
    94   1      200.0
     0   0      100.0
                     0.0      5.1      10.2      15.3      20.4
                                  Percentage
Including values outside displayed ranges        Sample Size:   9447
Horiz. Scale:      x1                            Average:      754 uS
Median Range: 700-800 uS                         Std. Dev.:    225 uS
```

Software Performance Analysis, like this distribution of a subroutine's execution times, helps you easily understand the activity of your code.



```
Cursor Seq:
 Seq     Address          Data     Mnemonics                State
 6597    main + 2F7C      4EB9     JSR     ser_io            (U)
 6791    ser_io + 84      61FC     BSR     put_byte          (U)
 6871    put_byte + 42    4E75     RTS                       (U)
 9600    ser_io + 12A6    4EB9     JSR     delay             (U)
11699    delay + 76       4E75     RTS                       (U)
11796    ser_io + 1324    61FC     BSR     comm_tst          (U)
11899    comm_tst + 76    4E75     RTS                       (U)
Cursor Seq:  14698
 Seq     Address          Data     Mnemonics                State
14697    io_int + 1C0     20DF     MOVE.L  (A7)+,D3          (S)
         0AFB26           0000      ( READ     )             (S)
         0AFB28           004B      ( READ     )             (S)
14698    io_int + 1C2     211F     MOVE.L  (A7)+,D4
         0AFB2A           0000      ( READ     )             (S)
         0AFB2C           00AB      ( READ     )             (S)
14701    io_int + 1C4     4E73     RTE                       (S)
               0        1        2        3        4        5        6        7
Data     00000000 00000000 807C002A 0000004B 000000A5 00000000 00000000 00000000
Address  00A000B6 0020C7FB 00000000 00000000 00000000 00000000 00000000 00F07C28
```

Step backwards through acquired data, including subroutines, stack and register models, using time-correlated split-screen displays to pinpoint problems.

In every dimension—speed, channel width, memory depth, trigger capability, modularity and ease of use—the DAS9200 dwarfs what's been possible before.

The DAS9200 features a tightly coupled, high-speed architecture in which multiple card modules can act as a single unit. Large color-coded displays, pop-up menus, performance analysis graphs, multi-tasking and more combine to uncomplicate logic analysis.

1 Apply state-driven triggering at 200 MHz with up to 384 channels of sync and async data acquisition.

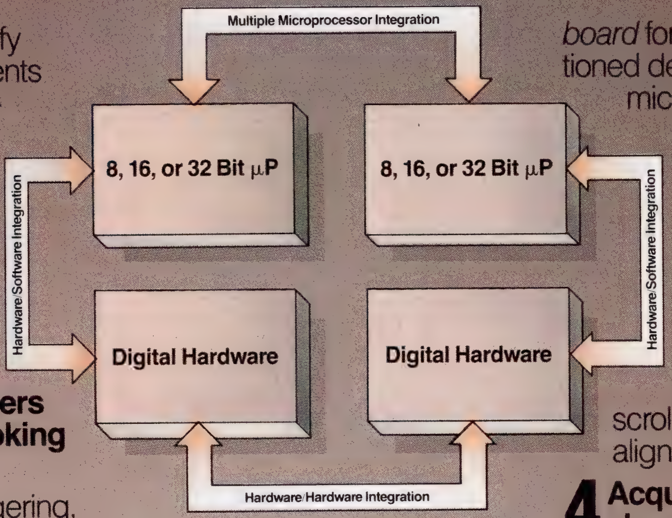
You can assurance-test high-speed logic at full speed, using 4-level state tracking and high speed counter/timers integrated into the 92A16 timing board.

You can monitor and verify all the timing measurements in a circuit, including setup and hold time, minimum pulse width, and precharge time, and quickly select common-test routines from the Trigger Library.

2 Register deduction and stack simulation let developers debug software by looking backwards in time.

Use the complex triggering, data qualification and 32K per channel memory of the 92A60/92A90 acquisition modules to monitor software activity in real time.

Continually updated register and stack displays let you quickly identify problems like stack overflow or incorrectly restored pointers—without breakpoints and manual notation.


Multiple Microprocessor Integration
8, 16, or 32 Bit μP
8, 16, or 32 Bit μP
Hardware/Software Integration
Hardware/Software Integration
Digital Hardware
Digital Hardware
Hardware/Hardware Integration

3 Split-screen time-correlated displays help you monitor and correlate up to six microprocessors at once.

Take the same system modules used in debugging the hardware and software and reconfigure them *from the keyboard* for integrating partitioned designs or multiple microprocessors.

Use the dual timebases and real-time handshaking between modules to set up split-screen displays of disassembly with timing or state table data. Lock the two cursors so that both screens scroll in precise time alignment.

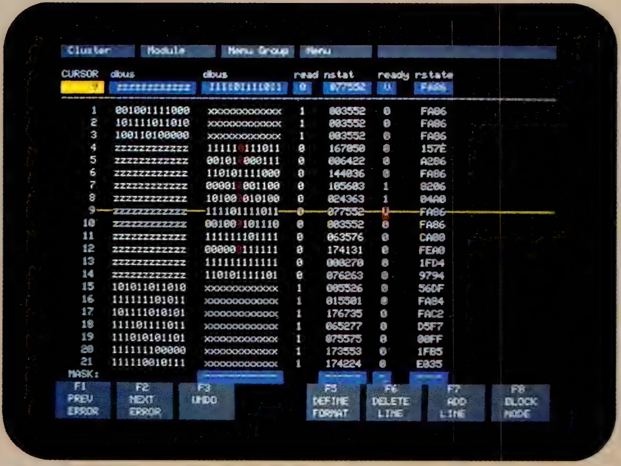
4 Acquire up to 160 channels at a full 2 GHz for unprecedented 500 ps sampling.

The 9200 offers the first acquisition unit to split the nanosecond: the 92HS8. With its 500 ps sample interval and 1.5 ns glitch detection, you can identify previously undetectable race conditions, spurious clocks and setup/hold violations in any logic family.

The 92HS8 is complemented by the world's most advanced probing system, featuring an input capacitance of less than 1 pf.

Available in desktop and rack-mount versions, the DAS9200 mainframe can be augmented with up to three expansion mainframes for a total of 28 card slots.

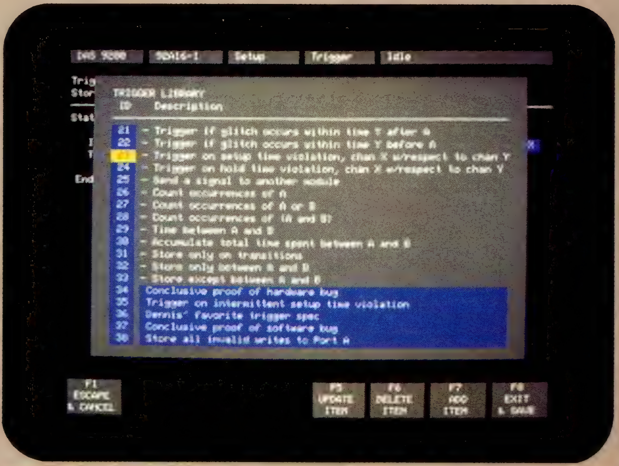
BENCHTOP ASIC OR PCB TESTS? YOUR WISH IS OUR COMMAND!



```
CURSOR  dbus          dbus          read nstat   ready rstate
     9  zzzzzzzzzzzz  111101111011  0    077552  U     FA86

     1  001001111000  xxxxxxxxxxxx  1    003552  0     FA86
     2  101111011010  xxxxxxxxxxxx  1    003552  0     FA86
     3  100110100000  xxxxxxxxxxxx  1    003552  0     FA86
     4  zzzzzzzzzzzz  111110111011  0    167050  0     157E
     5  zzzzzzzzzzzz  001010000111  0    006422  0     A206
     6  zzzzzzzzzzzz  110101111000  0    144036  0     FA86
     7  zzzzzzzzzzzz  000010001100  0    105603  1     8206
     8  zzzzzzzzzzzz  101000010100  0    024363  1     04A0
     9  zzzzzzzzzzzz  111101111011  0    077552  U     FA86
    10  zzzzzzzzzzzz  001000101110  0    003552  0     FA86
    11  zzzzzzzzzzzz  111111101111  0    063576  0     CA00
    12  zzzzzzzzzzzz  000000111111  0    174131  0     FEA0
    13  zzzzzzzzzzzz  111111111111  0    000270  0     1FD4
    14  zzzzzzzzzzzz  110101111101  0    076263  0     9794
    15  101011011010  xxxxxxxxxxxx  1    005526  0     56DF
    16  111111101011  xxxxxxxxxxxx  1    015501  0     FA84
    17  101111010101  xxxxxxxxxxxx  1    176735  0     FAC2
    18  111101111011  xxxxxxxxxxxx  1    065277  0     D5F7
    19  111010101101  xxxxxxxxxxxx  1    075575  0     00FF
    20  111111100000  xxxxxxxxxxxx  1    173553  0     1FB5
    21  111110010111  xxxxxxxxxxxx  1    174224  0     E035
MASK:
```

Results of the ASIC prototyping system can be displayed in timing or state format, with differences from expected results clearly highlighted.



```
TRIGGER LIBRARY
 ID   Description

 21 - Trigger if glitch occurs within time T after A
 22 - Trigger if glitch occurs within time Y before A
 23 - Trigger on setup time violation, chan X w/respect to chan Y
 24 - Trigger on hold time violation, chan X w/respect to chan Y
 25 - Send a signal to another module
 26 - Count occurrences of A
 27 - Count occurrences of A or B
 28 - Count occurrences of (A and B)
 29 - Time between A and B
 30 - Accumulate total time spent between A and B
 31 - Store only on transitions
 32 - Store only between A and B
 33 - Store except between A and B
 34   Conclusive proof of hardware bug
 35   Trigger on intermittent setup time violation
 36   Dennis' favorite trigger spec
 37   Conclusive proof of software bug
 38   Store all invalid writes to Port A
```

With the Trigger Library, you don't need to know the microprocessor microcode or the bits and bytes of trigger setup to tackle once-difficult problems.

5 The DAS9200 is available as a low-cost turnkey ASIC device verification system.

Featuring 50 MHz pattern generation, 8K bit vector depth, 1 ns edge placement and 0.5 V/ns slew rates, it is an accessible, easy-to-use alternative to centralized systems.

You can link to popular logic simulators, download test vectors, call up split-screen displays and analysis graphs, utilize multiple sets of patterns and parameter sweeps, and display results in timing or state format, with anomalies clearly highlighted.

6 The DAS9200 frees circuit board functional testing from costly and complicated central test systems.

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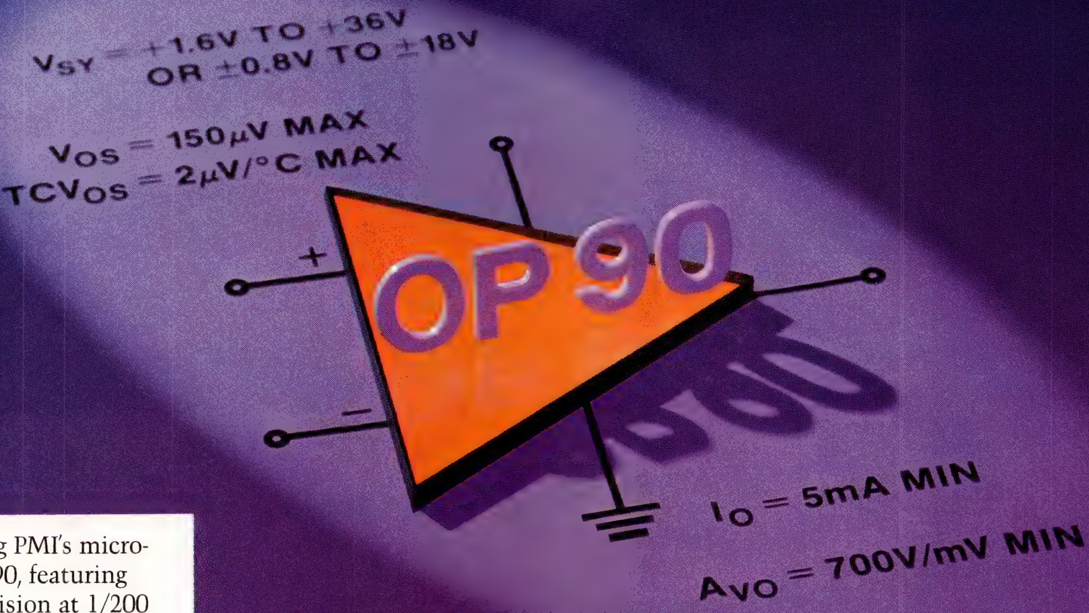
V_{SY} = +1.6V TO +36V OR ±0.8V TO ±18V
V_{OS} = 150μV MAX
TCV_{OS} = 2μV/°C MAX
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+
−
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A_{VO} = 700V/mV MIN

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V_{OUT}	0 to $(V_{SY} - 0.8V)$	V
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I_{OUT}	5	mA Min
V_{OS}	150	μV Max
A_{VO}	700	V/mV Min

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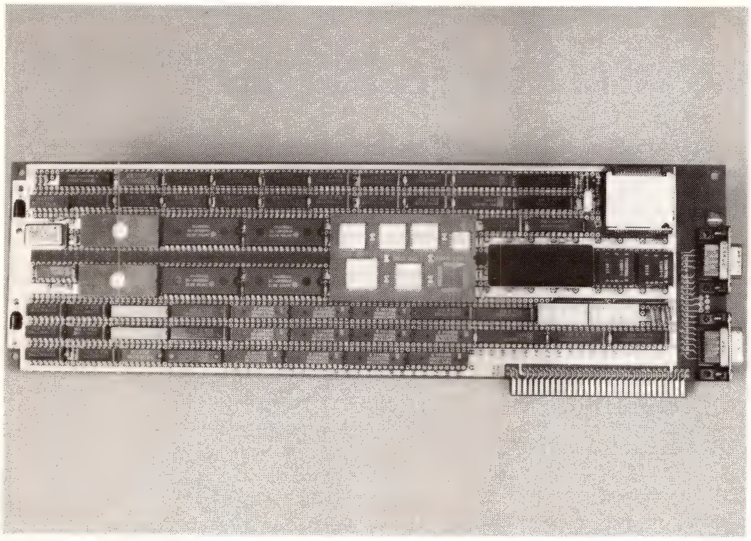

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CIRCLE NO 34

CALENDAR

Dexpo Europe (European DEC-Compatible Exhibition and Conference), London, UK. Expoconsul International, 3 Independence Way, Princeton, NJ 08540. (609) 987-9400. March 3 to 5.

CARTS '87 (Capacitor and Resistor Technology Symposium), Garden Grove, CA. Leon Hamiter, 904 Bob Wallace Ave, Suite 117, Huntsville, AL, 35801. (205) 536-1304. March 9 to 12.

Fourth Topical Meeting on Optical Data Storage, Lake Tahoe, NV. Optical Society of America, 1816 Jefferson Pl NW, Washington, DC 20036. (202) 223-0920. March 11 to 13.

Design and Manufacture of Surface Mount Technology (symposium), Longmont, CO. New Technologies and Design, Box 376, Longmont, CO 80502. (303) 651-2535. March 12 to 13.

Northeast Bioengineering Conference, Philadelphia, PA. IEEE, 6411 Chillum Pl NW, Washington, DC 20012. (202) 785-0017. March 12 to 13.

Personal Computer Interfacing for Scientific Instrument Automation, Blacksburg, VA. Linda Leffel, CEC, Virginia Tech, Blacksburg, VA 24061. (703) 961-4848. March 12 to 14.

Modern Electronic Packaging, Torrance, CA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. March 16 to 18.

International Military Fiber Optic and Communications Exposition, Washington, DC. Information Gatekeepers, 214 Harvard Ave, Boston, MA 02134. (617) 232-3111. March 16 to 19.

CIM in Practice—Company Experiences, Seattle, WA. Society of

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CIRCLE NO 37

CALENDAR

Manufacturing Engineers, Computer and Automated Systems Association, Greater Seattle Chapter #282, Box 1445, Renton, WA 98057. March 17 to 18.

Computer Graphics '87, Philadelphia, PA. National Computer Graphics Association, 2722 Merrilee Dr, Suite 200, Fairfax, VA 22031. (703) 698-9600. March 22 to 26.

IEEE VLSI Test Workshop, Atlantic City, NJ. Wesley Radcliffe, IBM, East Fishkill Facility, Bldg 321-5E1, Dept 277, Hopewell Junction, NY 12533. (914) 894-4346. March 24 to 25.

Southcon, Atlanta, GA. Electronic Conventions Management, 8110 Airport Blvd, Los Angeles, CA 90045. (213) 772-2965. March 24 to 26.

Internepcon/Semiconductor Korea '87, Seoul, Korea. Cahners Exposition Group, Box 70007, Washington, DC 20088. (301) 657-3090. March 26 to 28.

ADEE West '87, Anaheim, CA. Cahners Exposition Group, 1350 E Touhy Ave, Des Plaines, IL 60017. (312) 299-9311. March 31 to April 2.

Defense Communications Agency Forecast to Industry, White Oak, MD. Armed Forces Communications and Electronics Association NOVA Chapter, Computer Sciences Corp, 6565 Arlington Blvd, M/C DCA/AFCEA, Falls Church, VA 22046. April 1 to 2.

Microtronics '87, Hannover, West Germany. Hannover Fairs USA, Box 7066, Princeton, NJ 08540. (609) 987-1202. April 1 to 8.

Invitational Computer Conference, Nashua, NH. B J Johnson & Associates, 3151 Airway Ave, #C-2, Costa Mesa, CA 92626. (714) 957-0171. April 2.

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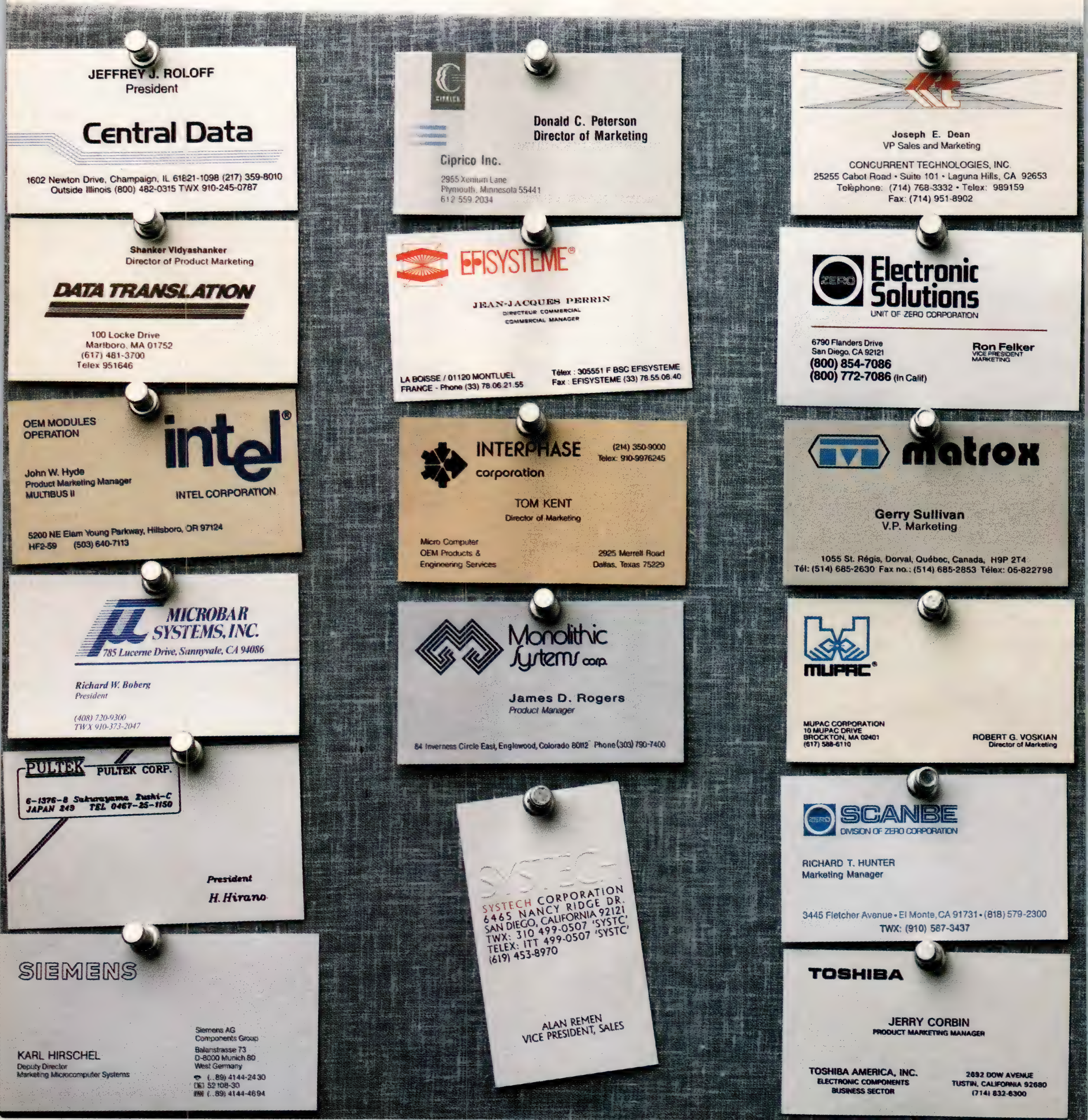

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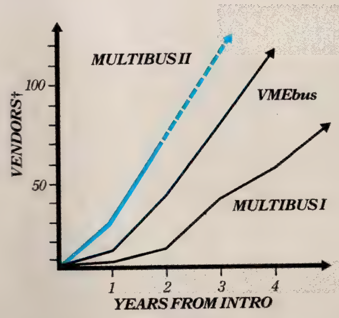

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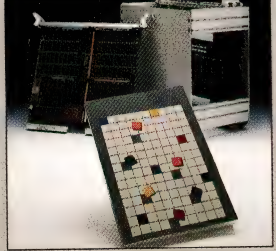

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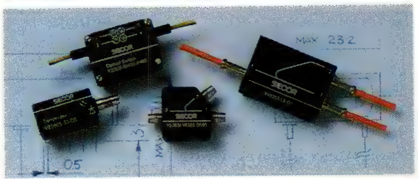

Left to right: 200 MBaud transmitter, fiber optic switch, WDM, T-coupler with pigtail.

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CIRCLE NO 39

NEWS FROM PHILIPS

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Improved signal conditioner for position sensing transducers

We are offering a precision signal conditioner, the SE/NE5521, for use with position sensing transducers such as linear variable differential transformers (LVDTs, linear phase differential transformers (LPDTs), and rotary variable differential transformers (RVDTs). The 16-pin IC offers many features suitable for a wide variety of applications such as: position sensing of aircraft rudders, flaps, or ailerons; brake sensing, throttle position, and fuel level gauges in transportation; precision weighing devices; and automated guidance systems and robotics. The circuit consists of three major building blocks: a sine wave oscillator with programmable frequency, a synchronous demodulator and an auxiliary amplifier. The oscillator has been designed for low distortion, stable amplitude and programmable frequency operation over time and temperature so that compensation for these parameters is no longer necessary. Design engineers no longer need to create circuitry to drive a transducer or convert its output to a d.c. voltage. Instead, the SE/NE5521 signal conditioner accepts parameters such as weight, force, pressure and acceleration which have been converted to linear displacement or linear rotation. The displacement or rotation information is conditioned by the IC to provide accurate measurement of the particular parameter.

Three versions are available: the NE5521 in plastic or cerdip DILs and SO mini-packs for the commercial temperature range (0 to 70 °C; the SA5521 in plastic and cerdip DILs for the automotive temperature range (−40 to 86 °C) and the SE5521 in cerdip DILs for the extended temperature range (−55 to 125 °C). All three versions offer an accuracy of 0,1 % in the linearity error over a supply voltage range of 5 to 20 V.

CIRCLE 10

Philips enters the 256 Kbit CMOS EPROM market

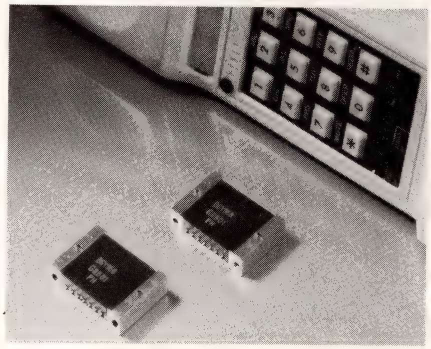
Philips, one of the world's leading suppliers of quality integrated circuits, has made a major entry into the CMOS EPROM marketplace with the introduction of their 256 Kbit EPROMs. The 27C256 is available now in production quantities, joining the 27C64A, a 64 Kbit CMOS UV EPROM released for production in July 1986. The 27C256 and the 27C64A are ideal for single or multiple chip microcomputers, portable test equipment and communications devices such as remote and cellular telephones where low power, non-volatile memory is required. Following suit with their history of being a broad line supplier, Philips plans to offer an entire family of CMOS EPROM products. The company also plans to use the newly-acquired CMOS EPROM process, the result of a technology agreement with Intel Corp., to develop other semiconductor products in their Programmable Products Group. The front-end manufacturing for both the 27C256 and 27C64A is located in the company's state-of-the-art Albuquerque, New Mexico CMOS fabrication facility.

The 27C256 is organized 32 K words by 8 bits and is available in 170, 200, 250 and 300 ns speed grades while the 27C64A is organized 8 K words by 8 bits and is available in 200, 250 and 300 ns speed grades. Both devices consume a maximum of only 55 mW of active power when driven with CMOS signals; standby power consumption is just 550 µW. The 27C256 and 27C64A offer high latch-up and noise immunity as a result of Philips' epitaxial CMOS processing.

Fully interchangeable with industry-standard CMOS and NMOS devices, the Philips' 27C256 and 27C64A can be programmed with standard EPROM programmers using a 12,5 V programming voltage. The 27C256 and 27C64A are packaged in standard 28-pin ceramic dual-in-line packages with a quartz window. Both devices are guaranteed over the commercial temperature range of 0 to 70 °C. The 27C64A is available in extended temperature versions now; for the 27C256 these versions will be available shortly.

CIRCLE 11

Power amplifier modules simplify design of portable cellular radio handsets



We are introducing two new ultrahigh frequency power amplifier modules, the BGY95 and BGY96, which each form a complete 3-stage radio frequency power amplifier, including bias circuits, in 900 MHz handheld cellular radio sets. The devices are optimized for operation at two different voltage supply standards to give OEMs maximum flexibility of handset design choice – the BGY95 operates from 7,5 V and the BGY96 from 9,6 V. Both modules produce 2,5 W of output power, more than any competing module in the marketplace for this category of handheld equipment. The output power can be controlled-down by d.c. voltage control to a mere 6 mW, a requirement demanded by modern cellular radio systems specifications.

For the frequency range 825 to 845 MHz (North America), the BGY95A and BGY96A are available. For the frequency range 860 to 915 MHz (the European standard) the BGY95B and BGY96B are available. The modules are in a seven-lead package and each consists of three npn silicon planar transistors mounted on a metallized ceramic substrate together with matching and bias circuitry. They are designed for operation into 50 Ω loads over the specified frequency bands. The 50 Ω impedance values, both at the input and the output connections of the modules, facilitate the design of the surrounding circuitry and reduce the required space for external matching circuitry.

CIRCLE 12

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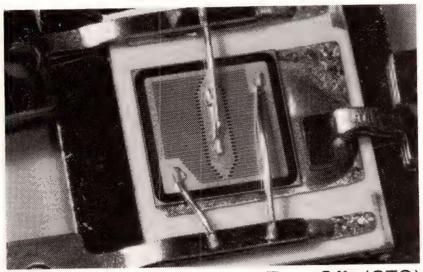
Expanding programmable logic sequencer line covers more circuit connection configurations

We are announcing the addition of two new devices to our bipolar field programmable logic sequencer range which allow designers to implement more complex state machines with programmable 10-bit embedded state registers. Application areas for the 24-pin PLS168 and PLS168A include interface protocols, sequence detectors, peripheral controllers, tuning generators, sequential circuits, elevator controllers, security locking systems, counters, shift registers and high-speed A-D converters. The PLS168 and PLS168A contain logic AND-OR gates with user-programmable connections which control inputs of on-chip state and output registers. With the addition of these devices the Philips PLD range, consisting of over 20 devices, now encompasses the complete gamut of device configurations and connections. Only Philips offers the unique function of embedded programmable S-R registers. Similar in architecture to the 24-pin PLS167 and PLS167A, the new devices have 48 transition terms which control the on-chip S-R (Set-Reset flip-flop) state and output registers. The PLS168/168A each have a total of six internal feedback registers that in combination with four registered output feedback paths provide 10-bit state machine capability. The new logic sequencers offer the same number of transition terms as the 28-pin 82S105/105A Field Programmable Logic Sequencer (FPLS) that has 16 dedicated inputs.

The PLS168 and the enhanced speed version, the PLS168A, with maximum clock frequencies of 13,9 and 20 MHz respectively, are designed for direct replacement of random logic clusters containing Schottky TTL gates and flip-flops. The embedded S-R flip-flops in the PLS168 inherently provide the 'hold' state necessary when using any controller function.

CIRCLE 13

One-chip GTO with diode provides performance, protection plus savings



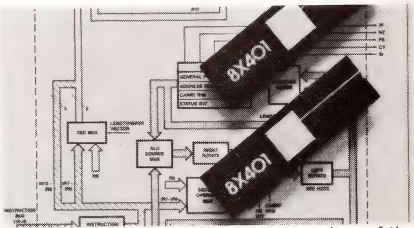
A series of 15 A Gate Turn-Off (GTO) thyristors just announced by Philips features an anti-parallel diode integrated on each chip. The three devices of the BTV60D series not only cost less than the equivalent, separate components – they also occupy less space, are more reliable and are quicker and easier to build into motor control circuits. The BTV60D series is designed for use in high-frequency inverters, power supplies and PWM a.c. motor control systems dissipating up to 11 kW and requiring an anti-parallel-connected flywheel or efficiency protective diode.

Characterized by a very fine cathode structure which allows for fast, efficient current control, the BTV60D thyristors can switch off an anode current of up to 120 A in less than 300 ns. The protective diode's reverse recovery time is 600 ns. The three types available offer repetitive peak off-state voltages of 850, 1 000 or 1 200 V. The non-repetitive peak on-state current goes up to 240 A, illustrating the rugged performance of the device. The average on-state current may be up to 25 A. The devices are supplied in the industry-standard, isolated TO-238AA package.

The BTV60D series was developed from the company's first second-generation GTO – the diodeless BTV60. Like earlier GTOs, these devices combine the best characteristics of both transistors and thyristors (i.e. speed, high forward voltage blocking in the off-state, high forward currents in the on-state). However, they can control much larger motors or replace twice the number of conventional GTOs.

CIRCLE 14

Speediest microcontroller offers user friendliness



We are unveiling the next generation of the industry's fastest microcontroller family. The centrepiece of the family – the 8X401 microcontroller, implemented with emitter coupled logic (ECL) technology – combines speed, a high degree of flexibility with peripherals, and an expanded bit-orientated instruction set to accommodate many sophisticated applications. The 8X401 offers a higher level of user-friendliness than preceding generations of microcontrollers. The 8X401 can fetch, execute, and generate the next instruction address for a 20-bit instruction in a minimum of 150 nanoseconds. Within one instruction cycle, the 8X401 can be programmed to input, merge, rotate, and mask single or multiple bit subfields, in addition to performing an ALU operation. This capability is between 10 and 100 times faster than solutions based on general-purpose MOS microprocessors or microcontrollers. The new microcontroller is the successor to and 35% faster than the popular 8X305 device, up until now the industry's fastest 8-bit control-orientated solution to real-time processing needs in data communications, robotics, industrial, space and military applications. The 8X401 has a slow clock request making it downward-compatible with slower-speed peripheral devices in the family. This allows 8X305 users to upgrade performance without changing their designs.

The new family provides a complete microsystems approach to high-speed controller solutions while at the same time expanding the horizon on system performance. Based on the popularity of the system's predecessors and the significant improvements of the new device, the 8X401 family will be a leading choice for system designers for the remainder of this decade.

CIRCLE 15

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CIRCLE NO 51

EDITORIAL

Artificial intelligence: Caveat emptor

In the 1930s, computer scientists proposed the theory of artificial intelligence (AI) and captured the imagination of science fiction enthusiasts who bombarded the American public with such fictional mechanical servants as Robbie the Robot, the Jetson family's maid Rosie, and Star Wars' R2D2. Thus AI seems a familiar concept, thanks to our childhood Saturday afternoon matinees.

This familiarity with the concept of intelligent machines has helped AI become a multibillion dollar industry—even though few off-the-shelf systems use traditionally defined AI techniques, and even fewer commercially available expert systems provide more than a sophisticated checklist of things to remember. Accordingly, here are some helpful caveats for anyone testing the AI waters:

- If you've never worked with AI, start small. Buy an inexpensive expert system shell to get a feel for the types of projects you could reasonably expect to pursue (see EDN, November 13, 1986, pgs 91-100).
- Some projects are too simple to automate. An expert system should allow an untrained individual to perform a sophisticated task, but if that individual could accomplish the task faster by referring to a manual, don't waste your time building an expert system.
- Try to get a demonstration of the software before you buy it. As with any kind of software, the manufacturer's claims might exaggerate the usefulness of the product.
- Don't be afraid to ask the manufacturer what the AI aspects of the product are. Just because software uses rules to order its database extractions doesn't mean that an algorithmic approach isn't the fundamental means for decision making. Ask whether the inference engine contains an interpreter and a scheduler, how conflicts in data or conclusions are resolved, whether the software provides nonmonotonic reasoning, and whether the system uses symbolic processing.
- Once you find out what AI techniques are used in the product, determine whether such techniques actually enhance the product's performance or if they are merely a marketing ploy.
- You needn't learn a specialized AI language such as Lisp or Prolog if you only want to build an expert system from a shell. These shells are actually user interfaces that buffer you from the internal mechanism of the software. You need to learn Lisp or Prolog only if you want to program in those languages.

Software marketers hope to convince us that artificial intelligence is necessary because there isn't enough of the natural variety to go around. Yet, computers are innately stupid. Granted they are fast, consistent, and tireless, but a computer never does more than it is instructed to do. It has no initiative, no creativity, and no common sense. AI researchers theorize that we can instruct a computer to be creative and innovative, yet with current technology this theory is valid only for narrowly defined tasks.

So, for now, artificial intelligence and your computer's natural stupidity remain closely related. The novice who is investigating the array of "expert" products should take along a few extra grains of salt to make the software vendors' claims palatable.

J D Mosley

J D Mosley
Regional Editor

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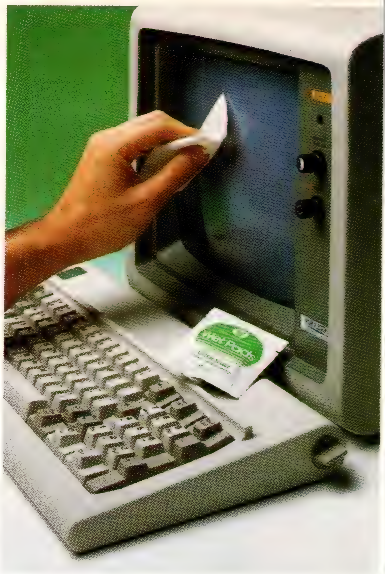

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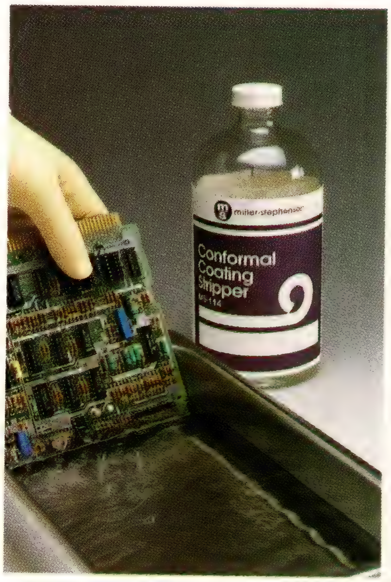

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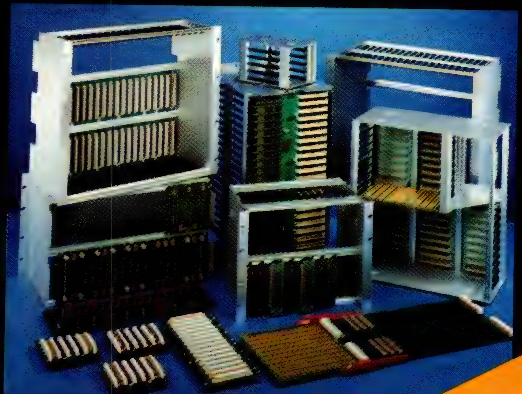

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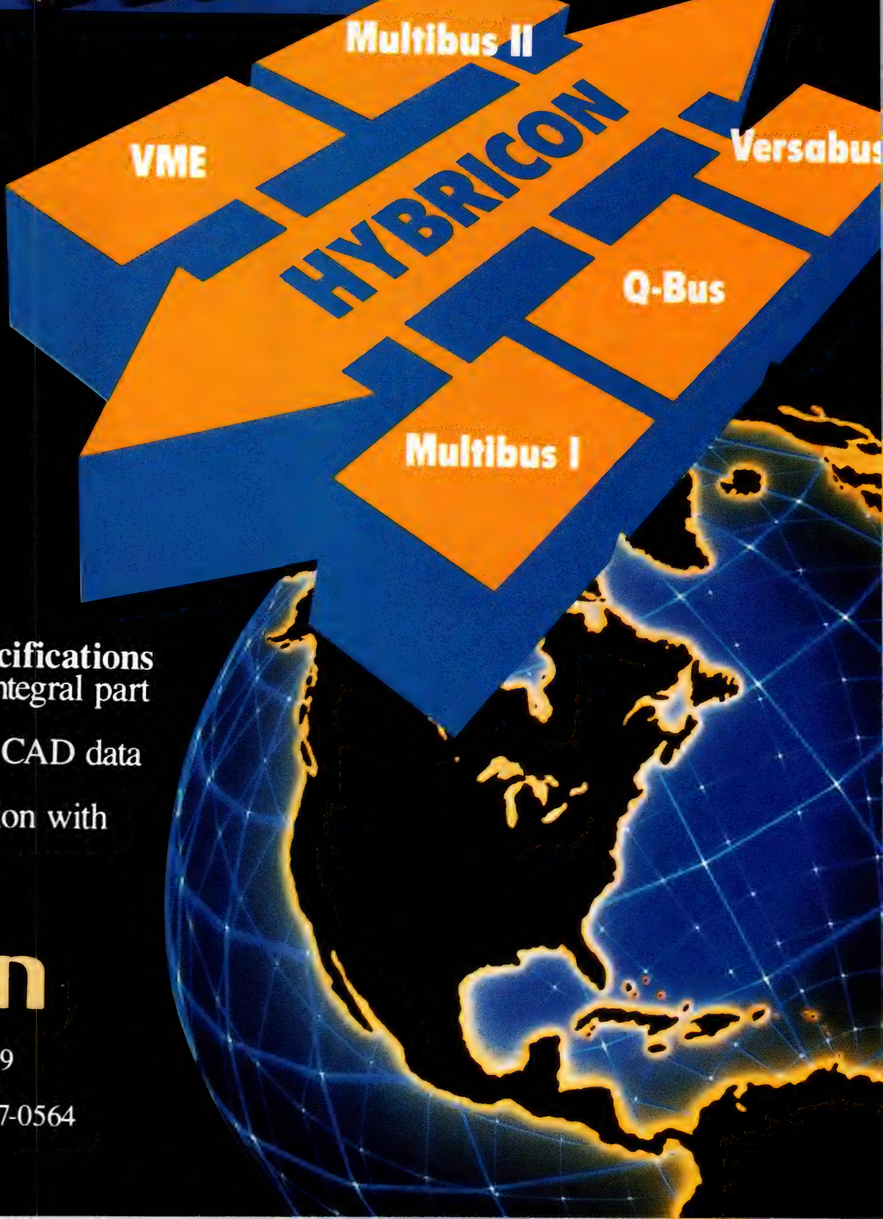

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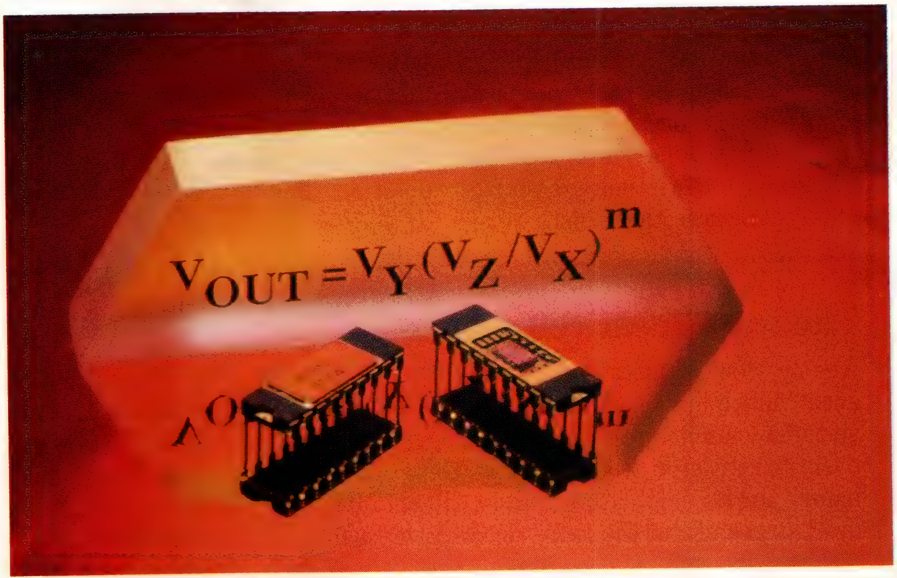
CIRCLE NO 53

Accurate, high-speed analog multipliers promise greater use of analog techniques

Tarlton Fleming,
Associate Editor



***Capable of performing simultaneous multiplication and division** or exponentiation in the range 0.2 to 5, this multifunction IC from Analog Devices, the AD538, offers an error spec of 0.25% of reading and a 400-kHz small-signal bandwidth.*

Multiplication of analog quantities has always presented a challenge. To compound the intrinsic difficulties of analog multiplication, many of today's potential multiplier applications call for higher bandwidth and lower distortion than available products can deliver. Yet the advent of much faster analog multipliers is imminent. These devices will extend the use of gain-control multipliers, for instance, to circuits of higher frequency than ever before.

Much of the demand for greater performance originates in military programs. In these applications, analog multipliers transform coordinates for plan-position-indicator (PPI) displays and fire-control systems, and they perform gain control, whether automatic (AGC) or manual, in radio, radar, sonar, and instrumentation systems. Gain-control circuits employ a basic property of the analog multiplier: Although it's a nonlinear device, the multiplier presents a linear channel to either input when you apply a constant control voltage to the other input.

Analog multipliers have come a long way since 1953, when Philbrick Researches of Boston offered a quarter-square multiplier that was capable of multiplying two voltages in the range −50 to +50V. This $600 unit, the K4-MU, measured 17×7×5.25 in., weighed 20 lbs, and consumed about 70W. Today's monolithic ICs do the same job much more quickly, of course, but the highest 3-dB bandwidth claimed for both inputs of these devices is well under 10 MHz. Even the hybrid Model 5890 from Optical Electronics specs just a 22-MHz small-signal bandwidth.

A brief technical review of the development of analog multipliers shows how far they have come and what directions they may take. The original quarter-square technique was based on the following principle:

$$XY = \frac{1}{4}[(X+Y)^2 - (X-Y)^2].$$

You obtain the product of inputs X and Y by performing those operations on the right side of the equation; op amps can accomplish all of these but the squaring operation (in itself a form of multiplication—in this design, you need a multiplier to build a multiplier). Early versions of the device employed the square-law relation between the plate current and grid voltage in a triode vacuum tube, and future designs may exploit the analogous relation between channel current and gate voltage in a MOS transistor. Many of today's quarter-square multipliers, however, use a piecewise-linear approach that's based on diode-breakpoint networks. The resulting cost and temperature sensitivity of these multipliers restricts them to applications such as low-frequency power measurement.

Also still in use are multipliers based on triangle-averaging and pulse-width/pulse-height modulation. These related techniques have historically provided higher accuracy than that of the available alternatives, at bandwidths as high as 100 kHz. Both types generate output ripple because they produce an ac waveform from which an rms output must be derived by filtering.

In the pulse-height/pulse-width multiplier, one input varies the duty cycle of a pulse train, and the other controls pulse amplitude, so the area under each pulse is proportional to the product of the inputs. Intronics pioneered the first multiplier of this type in 1966. Today, it offers the M310 and M311 as 3×3×0.42-in. modules. The M311, for instance, provides 0.03% max nonlinearity (Y input) and 10-mV p-p max feedthrough, and it operates over the industrial temperature range. It costs $281.60 (this and all subsequent prices are for quantities of 100).

Among the earliest multipliers was an electromechanical type used in World War II, based on the multiplying behavior inherent in a potentiometer: The wiper voltage equals the voltage across the resistive element times the wiper position (expressed as a fraction between 0 and 1).

In such a multiplier **(Fig 1)**, the motor and error amplifier move R_1's wiper until the wiper's voltage equals the input V_X. The wiper position then equals V_X divided by the fixed scaling voltage V_S, and the wiper of R_2 assumes the same position because the potentiometers are mechanically coupled. Therefore, $V_{OUT}=XV_Y$, where X is the wiper position V_X/V_S— that is, $V_{OUT}=V_XV_Y/V_S$.

This design allows linear components (potentiometers) to perform the nonlinear function of multiplication. You can also use nonlinear pots to generate nonlinear outputs such as trigonometric functions and their inverses, but in either case these multipliers are slow. The settling time for the V_X input is measured in seconds.

Although these multipliers are no longer in widespread use, if you could emulate the movable wiper of a potentiometer within a silicon chip, you could make a fast, solid-

The translinear-cell multiplier

Analog Devices introduced the first "transconductance" multiplier in 1971. This device, the AD530, and many similar products have depended on a basic 4-transistor cell called the "Gilbert cell," named for its originator, Barrie Gilbert. He, however, urges use of the more descriptive term "translinear cell," and points out that "transconductance multiplier" is a misnomer because it implies a conversion from voltage to current.

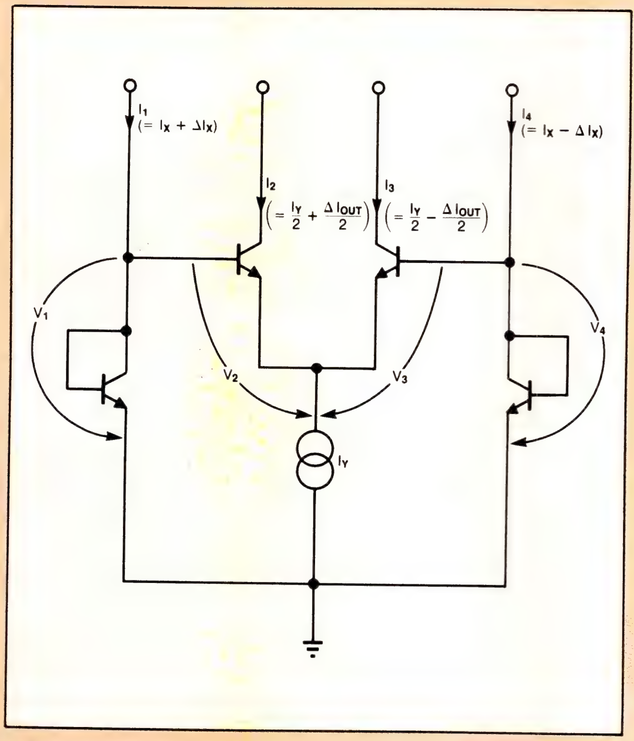

I_1
$(= I_X + \Delta I_X)$
I_2
$\left(= \frac{I_Y}{2} + \frac{\Delta I_{OUT}}{2}\right)$
I_3
$\left(= \frac{I_Y}{2} - \frac{\Delta I_{OUT}}{2}\right)$
I_4
$(= I_X - \Delta I_X)$
V_1
V_2
V_3
V_4
I_Y

Fig A—Forming the core of most manufacturers' multiplier ICs, *this translinear cell (also known as a Gilbert, or transconductance, cell) provides a linear transfer function that's insensitive to temperature changes.*

The basic multiplier cell **(Fig A)** is one of a distinct class of circuits (translinear circuits) for which operation is best described in terms of current flow. The cell's inputs and output are currents, and you can regard the internal base-emitter voltages merely as artifacts of the flow of bias and signal currents. More to the point, the translinear cell's ideal current-transfer function is linear and independent of temperature; these attributes provide an elegant solution to the problems of analog multiplication.

To appreciate the translinear cell's significance, note that analog multipliers of this type depend directly on two properties of the bipolar transistor: the log relationship between collector current and base-emitter voltage, and the linear relationship between transconductance (g_m) and collector current. The "log-antilog" multipliers such as Analog Devices' AD538 and Burr-Brown's 4302, for example, include op amps that convert the input voltages to currents, thereby providing drive for the internal current-input translinear multiplying cells. Op amps are considerably slower than the multiplying cell, so this approach trades bandwidth for design convenience.

In a simple form of the more prevalent type of translinear multiplier, the multiplier's X input drives the bases of a 2-transistor differential amplifier, while the Y input varies the amplifier's gain (g_m) by controlling the sum of collector currents:

$$g_m = \frac{dI_C}{dV_{BE}} = \frac{q}{kT}(I_C)$$

(where T is the absolute temperature, k is Boltzmann's constant, q is the unit of electronic charge, state version of **Fig 1**'s multiplier. Barrie Gilbert devised a way to do just that in 1969 while working at Tektronix. Now with Analog Devices, he may again champion the idea; such a multiplier would offer less noise and less thermally generated error than today's solid-state, translinear multipliers.

Using conventional process technology, you could fabricate the silicon potentiometer by first creating a long, narrow bipolar-transistor structure. The collector's buried-layer strip represents the pot's re-

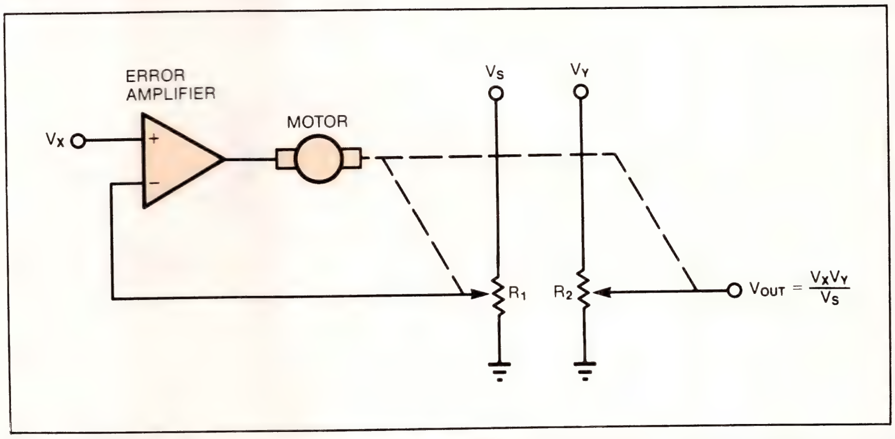


***Fig 1—This World War II-vintage analog multiplier** did the job, but it was bulky, power hungry, and slow.*

and I_C is the collector current). Because the Y input varies the transconductance, this configuration became known as a variable-transconductance multiplier.

For this simple example, the transistors' log property not only makes multiplication possible, but makes the X input nonlinear as well, which constitutes an unwelcome nuisance. Again, practical multipliers based on Gilbert's circuit avoid this drawback by providing a linear relationship between the input and output currents. To accept voltages, these multipliers must include (among other things) a linear stage at each input to convert the input voltage to a current.

Notice that the base-emitter and diode-connected transistor voltages sum to zero **(Fig A)** (translinear circuits include one or more loops, each comprising an even number of forward-biased pn junctions. Half of these junctions must conduct in a clockwise direction, the other half in a counter-clockwise direction):

$$V_1 - V_4 = V_3 - V_2. \qquad (1)$$

Each voltage is proportional to the logarithm of a current. For example,

$$V_1 = \frac{kT}{q} \ln\left(\frac{I_1}{I_{S1}}\right),$$

where I_{S1} is the small emitter-saturation current. Substituting these expressions in **Eq 1** and ignoring base currents yields

$$\frac{kT}{q} \ln\left(\frac{I_1}{I_{S1}}\right) - \frac{kT}{q} \ln\left(\frac{I_4}{I_{S4}}\right) = \frac{kT}{q} \ln\left(\frac{I_3}{I_{S3}}\right) - \frac{kT}{q} \ln\left(\frac{I_2}{I_{S2}}\right).$$

Dividing each side by kT/q and rearranging yields

$$\ln\left(\frac{I_1 I_{S4}}{I_4 I_{S1}}\right) = \ln\left(\frac{I_3 I_{S2}}{I_2 I_{S3}}\right).$$

Because physically identical devices have equal I_S,

$$\ln \frac{I_1}{I_4} = \ln \frac{I_3}{I_2}.$$

Therefore,

$$\frac{I_1}{I_4} = \frac{I_3}{I_2}. \qquad (2)$$

The last result shows a temperature-independent, linear relationship between the differential input current $(I_1 - I_4)$ and the differential output current $(I_3 - I_2)$. That is, assuming negligible base currents and perfect device matching, the diode-connected transistors' log properties have perfectly compensated (that is, linearized) the relationship between collector current and base-emitter voltage in the other two transistors.

To demonstrate that **Fig A**'s circuit multiplies the differential input current (I_X) by the control input current (I_Y), simply substitute the quantities in parentheses for the corresponding currents in **Eq 2.** You can simplify the resulting equation to obtain

$$\Delta I_{OUT} = \frac{(\Delta I_X) I_Y}{I_X}.$$

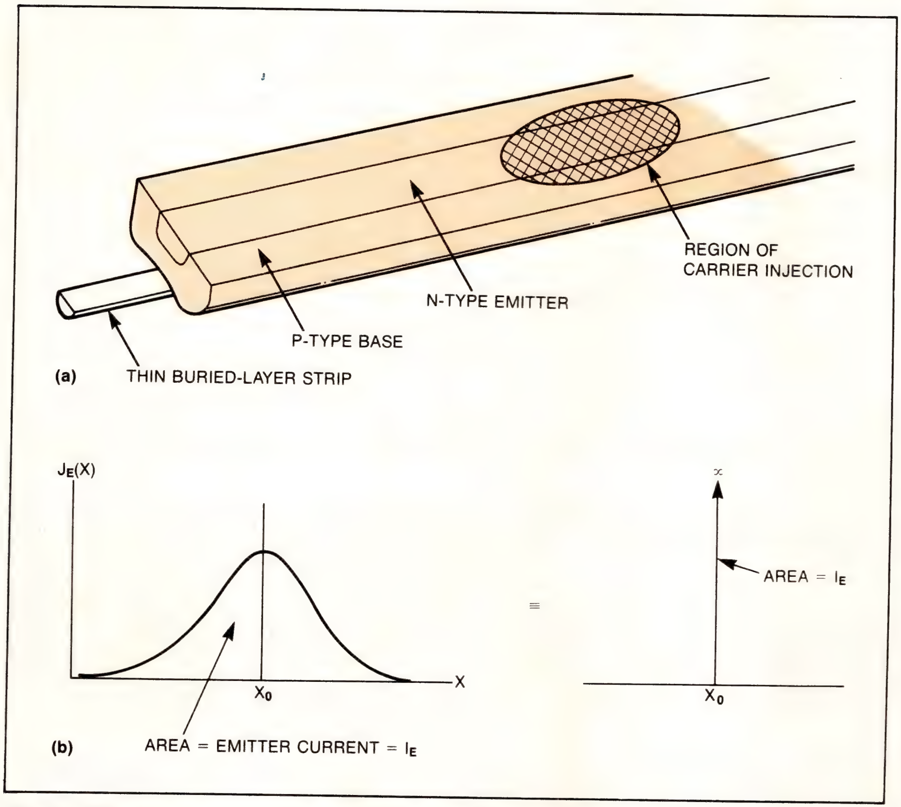


***Fig 2—This structure (a) is one end of the long, narrow bipolar transistor** that forms the foundation of an IC potentiometer. A Gaussian-shaped region of carrier injection **(b)** along the emitter actually behaves as a point of injection, thereby defining a precise position for the wiper.*

sistive element **(Fig 2a)**, and a region of intense minority-carrier injection along the emitter simulates the wiper position. Although the Gaussian-shaped carrier-injection region occupies about 10% of the emitter's length, the region's centroid defines a precise point of injection that looks like an impulse of current **(Fig 2b)**.

The analogy with a linear, electromechanical potentiometer is apparent in **Fig 3**, where the differential output current $I_E(1\text{-}X)\text{-}I_E(X)$ is a linear product of I_E and the normalized emitter position X.

If you create a parabolic voltage distribution along the base, you can change the carrier-domain (wiper) position by tilting the parabola **(Fig 4)**. You achieve tilting by controlling the voltages V_0 and V_1 at either end of the base; when $V_0=V_1$, for example, the wiper is at the midpoint (X=0.5). Unbalancing these voltages in either direction produces a smooth and linear change in X, allowing you to set the wiper anywhere from X=0 to X=1.

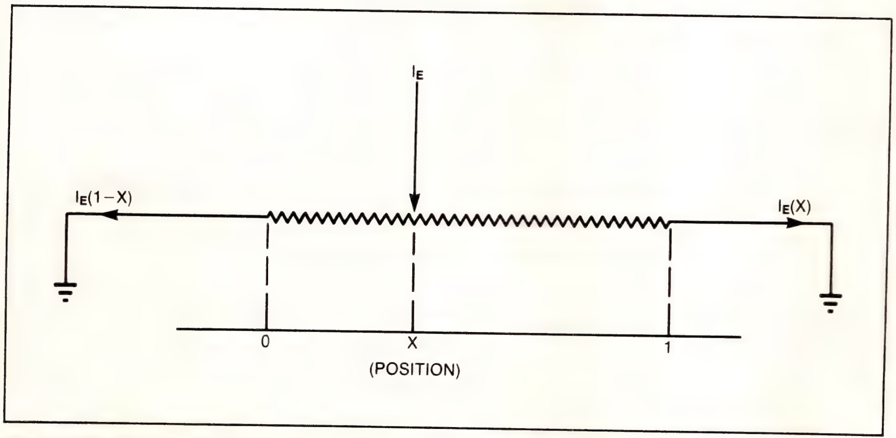


***Fig 3—The differential output current** $I_E(1-X)-I_E(X)$ corresponds to the electromechanical potentiometer's wiper voltage, and I_E corresponds to the voltage across the pot's resistive element.*

Finally, you generate the voltage parabola by injecting a sheet of current (I_B) into the base—that is, a constant current per unit of length of the base resistance (R_B). The resulting voltage distribution has a peak value of $I_BR_B/8$, which establishes the V_X input's full-scale value and, consequently, the multiplier's denominator scaling voltage.

Wide bandwidth is coming

For the more immediate—and more certain—future, new analog multipliers that will appear before mid-1987 promise a dramatic increase in speed. Analog Devices has scheduled the introduction of products that will spec bandwidth in the hundreds of megahertz. The company's last multiplier introductions were in 1983 (the AD539) and 1979 (the AD632), partly because it has concentrated instead on process development expressly for the fabrication of wideband analog multipliers. According to some observers, such components may help bring about a renaissance in the use of all-analog signal-processing techniques, particularly for higher-bandwidth applications.

Today, perhaps the fastest analog multiplier commercially available is Optical Electronics' $117 Model 5890. Intended for video applications, this hybrid, translinear device offers 4-quadrant operation and specs a typical 3-dB bandwidth of 22 MHz for 100-mV pk signals.

Burr-Brown carries an extensive line of analog multipliers, dividers, and multifunction converters. The hybrid multifunction converter ($19.60, Model 4203J), for example, uses the log properties of three individual transistors to add and sub-

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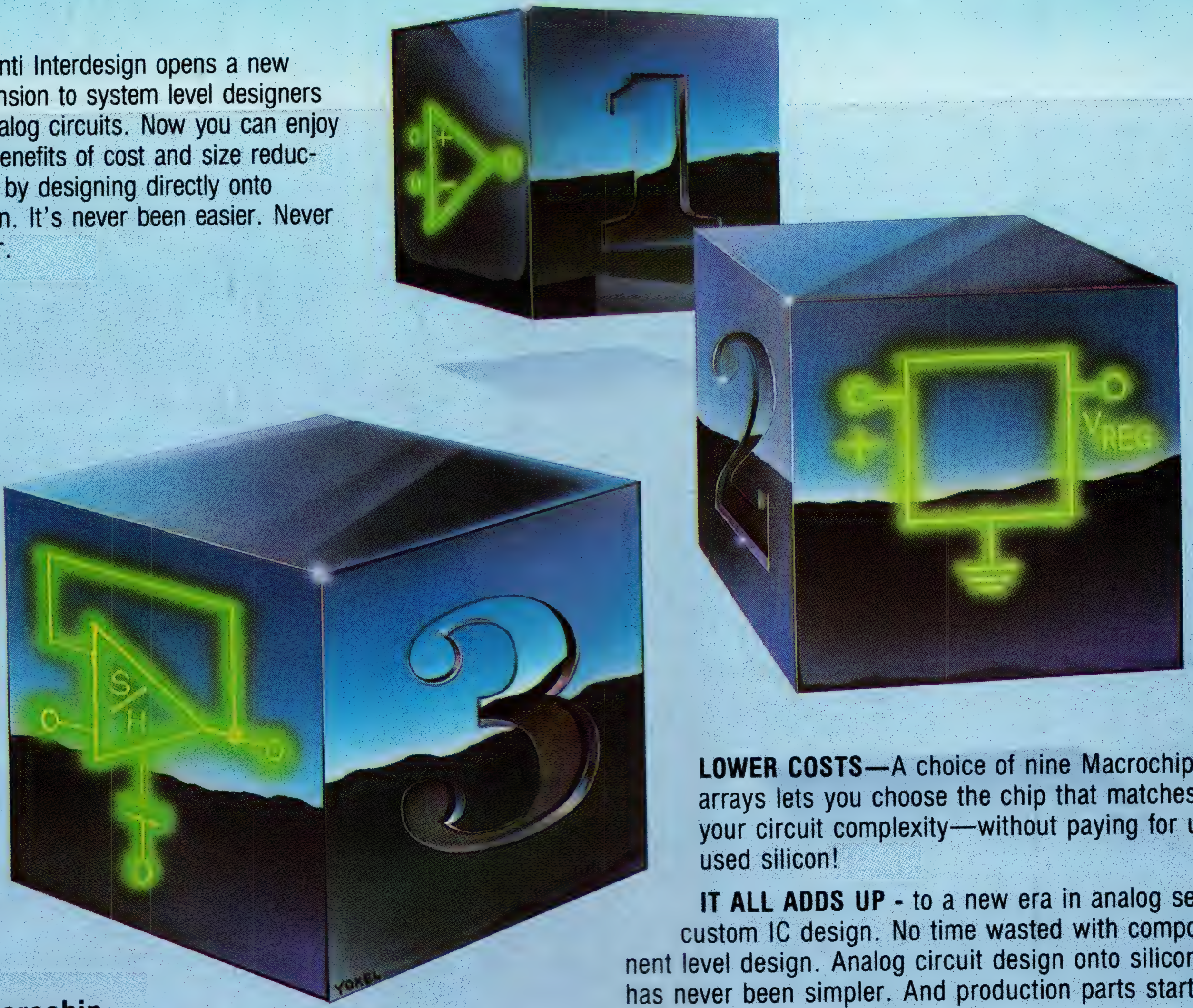

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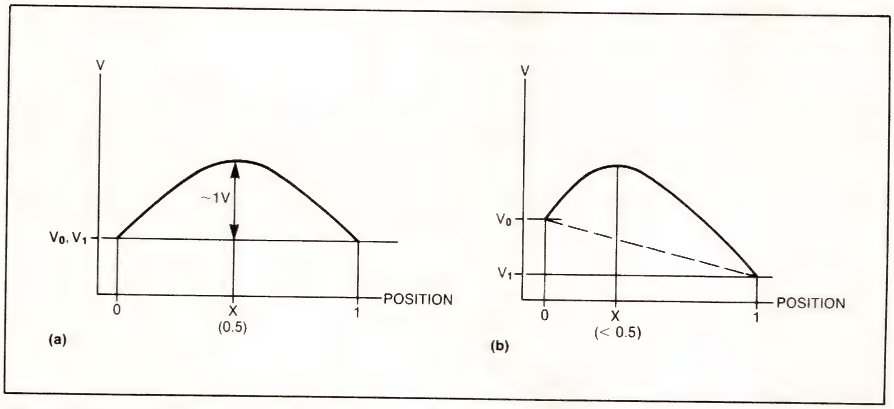

Fig 4—End-point voltages V_0 and V_1 *control the IC potentiometer's wiper position by "tilting" the resistive element's parabolic voltage distribution.*

tract input-voltage logarithms as you would with a slide rule. Then a fourth transistor connected in the antilog mode converts the answer to an output voltage. The result is a versatile transfer function that lets you raise an input ratio V_Z/V_X to the m power ($0.2 \leq m \leq 5$), or, with $m=1$, perform multiplication and division simultaneously. Operation is single-quadrant because all inputs must be positive:

$$V_{OUT}=V_Y(V_Z/V_X)^m.$$

Quadrants refer to the four regions of a Cartesian plane, and a multiplier's quadrant of operation refers to the combinations of input polarity for which the device produces a valid output. If both inputs must be unipolar, the operation is single-quadrant (quadrant 1 if the inputs must be positive, for example). If both inputs can be bipolar, the operation is 4-quadrant, and if either input (but not both) can be bipolar, the operation is 2-quadrant. Most divider circuits can only be 1- or 2-quadrant devices, because they can't allow a change of sign in the denominator.

For more information . . .

For more information on the analog multipliers described in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

Analog Devices Inc
2 Technology Way
Norwood, MA 02062
(617) 329-4700
Circle No 701

Burr-Brown Corp
Box 11400
Tucson, AZ 85706
(602) 746-1111
Circle No 702

Exar Corp
Box 3575
Sunnyvale, CA 94088
(408) 732-7970
Circle No 703

GE/Intersil Inc
10600 Ridgeway Court
Cupertino, CA 95014
(408) 996-5000
Circle No 704

GE/RCA
Solid State Div
Rte 202
Somerville, NJ 08876
(201) 685-6000
Circle No 705

Intronics Inc
57 Chapel St
Newton, MA 02158
(617) 964-4000
Circle No 706

Motorola Inc
Semiconductor Products Sector
Box 52073
Phoenix, AZ 85072
(602) 952-3613
Circle No 707

Optical Electronics Inc
Box 11140
Tucson, AZ 85734
(602) 624-8358
Circle No 708

Raytheon Co
Semiconductor Div
350 Ellis St
Mountain View, CA 94043
(415) 968-9211
Circle No 709

Silicon General Inc
11651 Monarch St
Garden Grove, CA 92641
(714) 892-5531
Circle No 710

Analog Devices' $17.50 AD538AD multifunction converter has an architecture similar to that of the 4302, but on-chip circuitry lets you configure it easily for 2-quadrant multiplication and division, performed with greater range (1000:1) and precision (±0.25% of reading over a 100:1 range). Raytheon's $3.20 current-mode RC4200 is another log-antilog device. It offers 4-quadrant multiplication and 2-quadrant division, but it doesn't perform general noninteger exponentiation. Its transfer function is $I_{OUT}=I_YI_Z/I_X$.

The majority of today's analog multipliers are 4-quadrant types based on the translinear cell (see **box**, "The translinear-cell multiplier"). Prices vary widely according to whether the multipliers are laser-trimmed and other factors. In addition to gain control and coordinate transformation, you can use these devices for power measurement, balanced modulation, rms-to-dc conversion, and function generation and linearization. Older versions include precision types from Analog Devices and Burr-Brown. Motorola and Silicon General offer low-cost versions represented by the 1495. Silicon General's SG1495N, for example, costs $1.35.

Exar's $1.86 translinear XR2228CP suits use as a phase detector in PLLs, and the $1.66 XR-2208CP is a higher-frequency, general-purpose multiplier. Both these 4-quadrant translinear types include an uncommitted op amp. In addition, the 2208 has a buffer amplifier that extends the 3-dB bandwidth from 3 to 8 MHz.

The $4.20 ICL8013CC TZ from Intersil is a translinear, 4-quadrant multiplier in a TO-100 package. Its onboard op amp provides a 3-dB bandwidth of 1 MHz and lets you configure the device with a mimimum of external components for division and calculation of square roots. The CA3091D from GE/RCA, also a 4-quadrant, translinear de-

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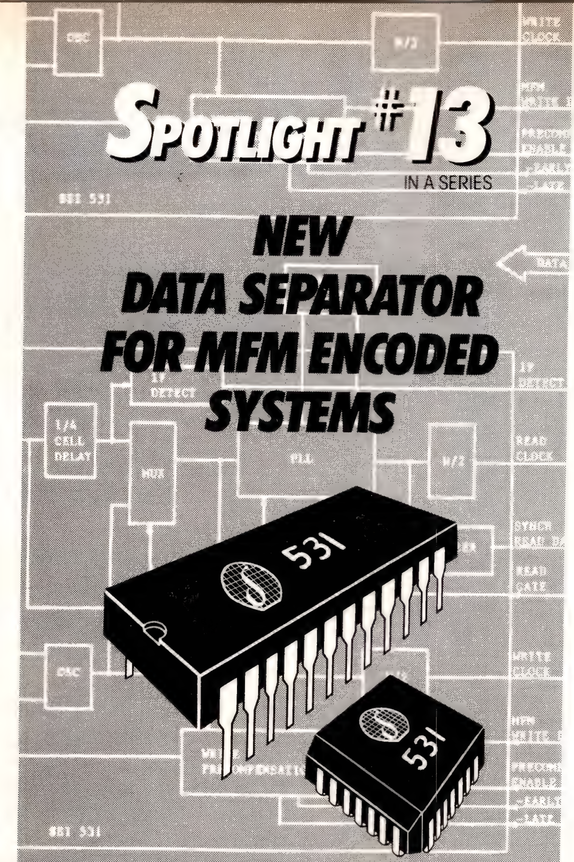

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The 531 has been developed in an advanced bipolar process for precise bit cell control, resulting in reduced system sensitivity to bit jitter and superior error rate performance. It operates from the +5V power supply, and it is priced under $10 in OEM production quantities.

For more information, contact: **Silicon Systems,** 14351 Myford Road, Tustin, CA 92680. **(714) 731-7110,** Ext. 575.

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INNOVATORS IN INTEGRATION

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vice, requires external resistors for voltage-mode operation. This $1, 4.4-MHz multiplier comes in a 14-pin ceramic DIP and offers 2.6% typ accuracy.

Representative modular, 4-quadrant, translinear multipliers from Intronics include the $64.40 M440, which specs a 0.6% max nonlinearity error and a 1-MHz typ 3-dB small-signal bandwidth. It comes in a 1×1-in. package. The $178.60 M510 high-speed version specs a 0.3% typ nonlinearity error and a 5-MHz min 3-dB small-signal bandwidth. It comes in a 1.5×1.5-in. package.

Analog Devices' $13.25 translinear AD539KN has two 60-MHz single-ended signal channels and a common 5-MHz control input. Developed expressly for gain-control applications, the device offers a maximum total error of 1.5% FS and comes in a 16-pin DIP. For 4-quadrant multiplication or 2-quadrant division, the $11.65 AD632AH provides the versatility of differential X, Y, and Z inputs. This laser-trimmed IC further offers a 1-MHz max 3-dB bandwidth and a 1% max error for 4-quadrant multiplication. It comes in a 14-pin DIP.

From Burr-Brown, the $36.85 translinear MPY534LD also offers differential X, Y, and Z inputs and laser-trimmed thin-film resistors. It provides a maximum 0.25% error for 4-quadrant multiplication. The small-signal 3-dB bandwidth is 3 MHz typ; the package is a 14-pin DIP. For wider-bandwidth applications, you can turn to the 10-MHz, $15.25 MPY634BM. Like the MPY534, this multiplier has differential X, Y, and Z inputs and a precision-output op amp that handles division and square-root operations with few external components. **EDN**

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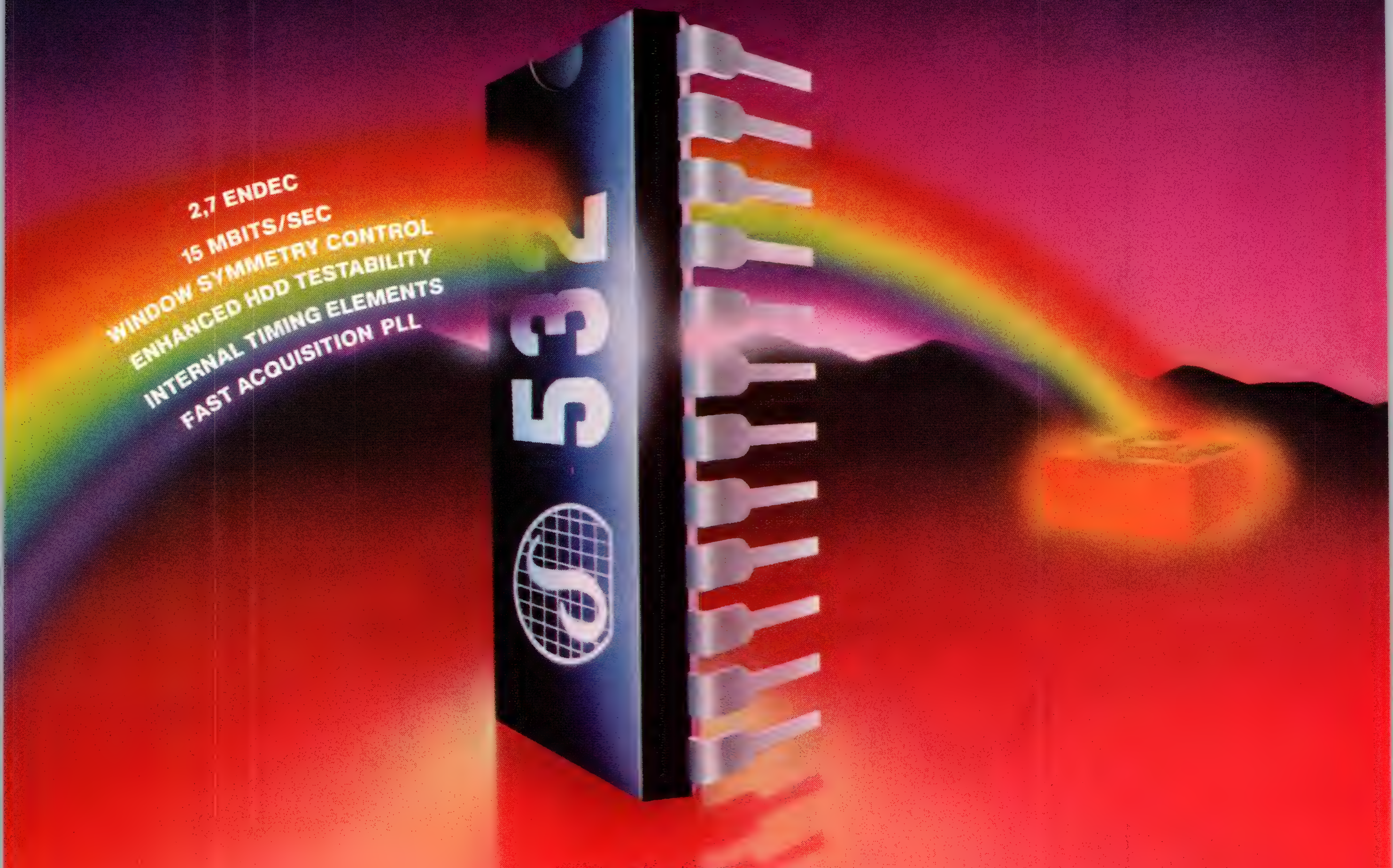

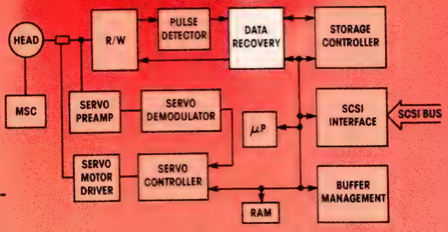

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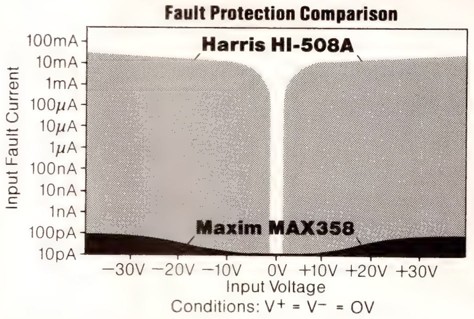

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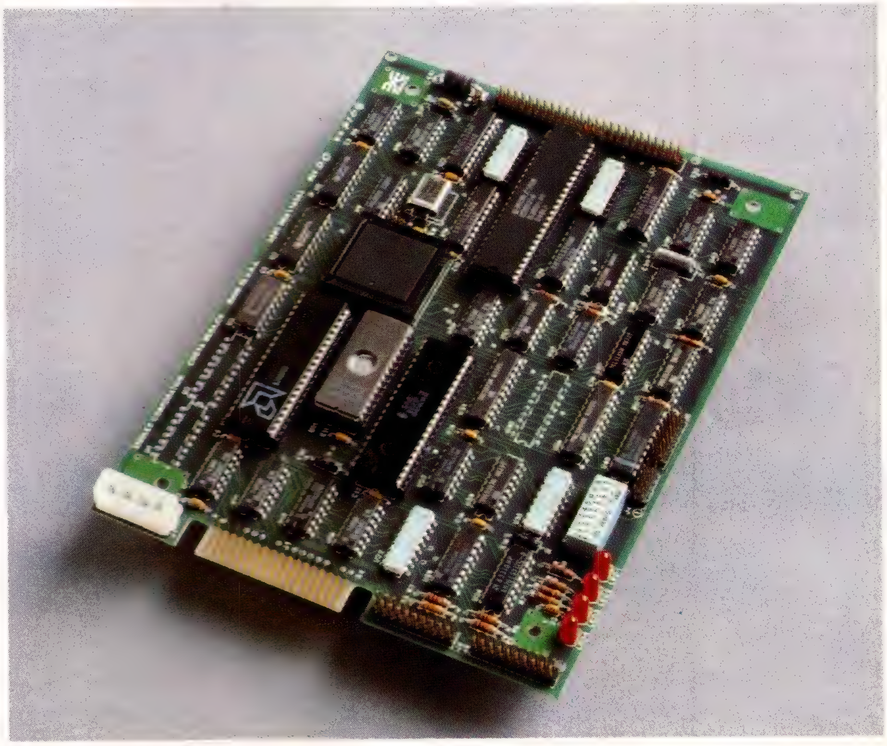
Bridged SCSI controllers remain viable regardless of emerging embedded controllers

Maury Wright, *Regional Editor*

Despite being threatened with extinction by peripherals with embedded controllers, bridged SCSI controllers allow users flexibility in I/O-subsystem design. Although not restricted just to Winchester disks, a bridged controller can provide cost-effective and enhanced performance benefits for such an application. Bridged controllers are well suited to serve multiple peripherals with device-level interfaces, and manufacturers use the added pc-board real estate inherent in bridged designs to add features and functionality not found in embedded controllers.

A bridged, or stand-alone, controller board provides the interface between the SCSI I/O bus and peripherals with device-level interfaces. For the most part, you choose a drive for a given system application. Examples of bridged controller boards for Winchester-disk applications include SCSI to ST-506/412 (SCSI/ST-506), SCSI/ESDI (Enhanced Small Device Interface), and SCSI/SMD (Storage Module Device) controllers.



ESDI data rates don't reach 24M bps yet, *but the Emulex MD21 SCSI/ESDI controller can handle transfers that fast now.*

Combine functions

A peripheral with a device-level interface (such as ESDI) includes a pc board that controls head movement and the reading and writing of data. Any controller board (no matter whether bridged or bus resident) performs functions such as translating logical addresses to physical addresses, buffering data, and issuing device-level commands. Typically, a system designer stacks a bridged controller on top of the device-level interface board. As an alternative, disk manufacturers offer embedded SCSI controllers, which combine the controller-board and device-interface function (for more information on SCSI I/O configurations, see **Refs 1** and **2**.)

Up until the last 12 to 18 months, you practically had no choice for your SCSI implementation other than a bridged controller. Nowadays, however, ICs specialized for the SCSI interface, buffer management, the controlling of head movement, and other functions allow peripheral manufacturers to design embedded controllers. Some disk manufacturers and industry observers believe embedded controllers will make stand-alone controllers obsolete.

The embedded-SCSI-controller proponents make good points for their cause. The embedded scheme essentially eliminates a link in the I/O chain. By eliminating the controller you may save money, and you'll also increase MTBF. Furthermore, you avoid situations where you are not sure if a problem exists in the drive or controller. Moreover, you simplify incoming-inspection and inventory control. Finally, you reduce the engineering evaluation/integration time required to match drive and controller.

Nonetheless, stand-alone controllers may well suit your needs better. You need to consider the application (of course), capabilities, overall system-performance requirements, and cost.

In some instances, your application may warrant the added features available on the two pc boards requisite in bridged-controller de-

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signs. For example, buffer size may be critical. Large buffer memories allow a controller to store multiple tracks of data. Western Digital, Emulex, and SMS offer SCSI/ESDI stand-alone controller boards that include 64k bytes of buffer memory. Most embedded controllers (and some bridged-controller boards) have buffers of less than 16k bytes.

John Kanzler, a product manager at Western Digital, admits that silicon densities will soon allow embedded-controller designs with 64k bytes of buffer memory. He believes, however, that by the end of 1987 bridged-controller products will routinely include one megabyte of memory. Kanzler also maintains that bridged controllers will continue to lead embedded controllers in such aspects as memory size and enhanced features.

Controllers offer MFM and RLL

Virtually all the first bridged-controller boards worked with ST-506 drives, but, as the ESDI has more and more become the device interface of choice (other than for personal-computer applications), newer and higher-performance boards support the ESDI rather than the ST-506.

Western Digital offers a variety of bridged-controller boards for Winchester disk drives. On the low end, the company offers the WD10003A-SCS SCSI/ST-506 board that employs MFM encoding and the WD1003R-SCS SCSI/ST-506 board with RLL encoding that offers a 50% increase in capacity and data rate. Each of the boards can control two drives. The MFM product costs $85; the RLL version sells for $95 (1000).

Western Digital's ADSI-D200 family of products is intended for the ESDI. (Western Digital recently bought Adaptive Data Systems Inc and markets products originating from both companies.) The basic ADSI-D200 supports four ESDI drives, comes with a 64k-byte buffer, and costs $190 (1000). The board handles the 10M-bps ESDI rate. It operates asynchronously at 1.8M bytes/sec max over the SCSI bus, although the standard specifies 1.5M-byte/sec max asynchronous transfers.

This quarter, Western Digital plans to start shipping a new version of the board, the ADSI-D200S. The new product makes use of new ICs and actually costs less—$155 (1000)—than its predecessor. The ADSI-2000S operates in an asynchronous mode at 1.8M bytes/sec or in a synchronous mode at 2M bytes/sec. The basic version of the product supports an ESDI rate between the interface and the controller of 10M bps.

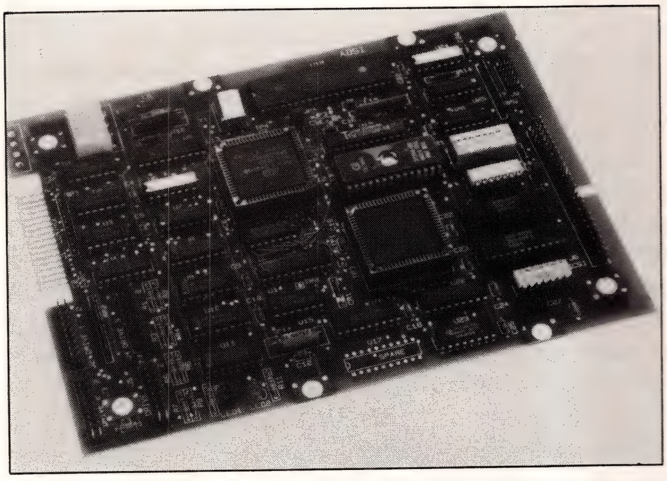
The company has plans to enhance both the controller's SCSI and ESDI performance. For example, future versions of the board will advance the data rate to the maximum 4M-byte/sec SCSI synchronous data rate and will support proposed ESDI-rate changes to 15M bps.

Board operates at 24M bps

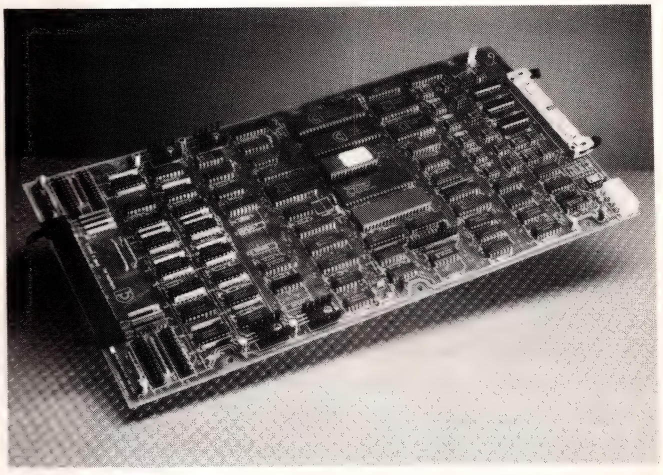
Emulex takes a similar approach with its SCSI/ESDI controller boards. The $395 MD21 controls two drives and has a 32k-byte buffer, whereas the $435 MD23 controls four drives and has a 64k-byte buffer. The Emulex boards support 1.25M-byte/sec asynchronous transfers but will handle ESDI data rates as fast as 24M bps when and if drives are ever built that fast. Emulex also offers the MD01 SCSI/ST-506 controller for $395.

These controllers also offer firmware flexibility. For example, you can program them in 1-byte increments for sector sizes ranging from 256 to 4096 bytes.

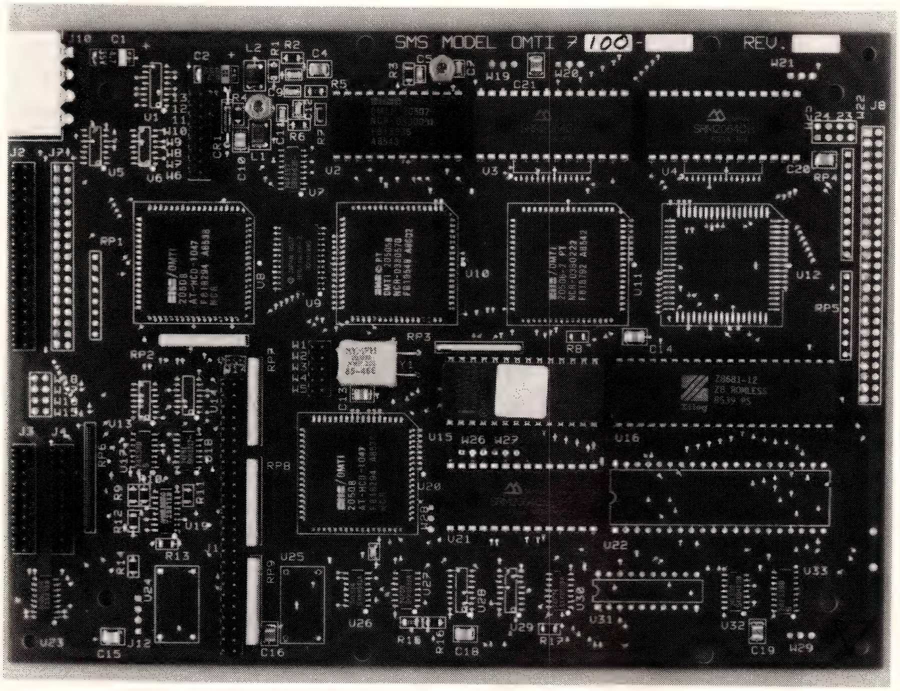
The company's product line also includes the $515 MD24 board, which duplicates the MD23 function but includes differential bus transceivers. Differential transceivers extend total SCSI cable length to 20m; 6m is the maximum for single-ended transceivers. Differential transceivers require more pc-board space, though, and so it's difficult for em-



The ADSI-D200 SCSI controller, *sold by Western Digital, contains a 64k-byte buffer, is compatible with the ESDI interface, and offers asynchronous and synchronous operation.*



This SCSI/SMD controller board *is representative of Adaptec's ACB-5500 family. This family of boards accommodates various device-level interfaces with minimal operating-system impact.*



Offering ESDI, ST-506, floppy-disk, and tape interfaces *on one board, the SMS OMTI 7000 family satisfies requirements spanning the spectrum of SCSI controller applications.*

bedded controllers to include the differential-transceiver option.

Although the companies mentioned above (and other companies as well) believe that stand-alone controllers, with their feature-rich designs, are well equipped to compete against embedded controllers, some of the companies also plan to compete by offering controllers of different levels of complexity. Kanzler of Western Digital, for example, claims that the company can easily vary the features that ADSI-D200S-family products provide—and the price charged. On a semicustom basis, Western Digital will vary such specifics as buffer size, the speed of the controlling μP, and firmware features.

In contrast, Winchester-disk-drive vendors may have a tougher time matching embedded-controller features to customer applications. In general, the Winchester-disk-drive manufacturers don't have near the controller expertise that the bridged-controller houses do. In fact, virtually all drive vendors (both tape and disk) have depended on controller houses for ICs and for expertise in designing embedded controllers.

Both Marty Francis, NCR engineering manager, and Jeff Miller, Adaptec's vice president of marketing, agree that bridged-controller manufacturers can easily provide custom firmware features. Miller claims that the controller houses have been providing custom features for all the different drive manufacturers for years, and these manufacturers have the engineering talent in-house to continue such capabilities.

For low-end applications, Adaptec offers the ACB-4000 family of controllers. The ACB-4000A SCSI/ST-506 employs MFM encoding, the ACB-4070 SCSI/ST-506 uses RLL encoding, and the ACB-4520 suits low-performance SCSI/ESDI applications. The -4000A and -4070 boards cost $127, and the -4520 costs $165 (1000). Each of the boards can control two drives.

For high-performance applications, Adaptec manufactures the ACB-5500 SCSI/ST-506 controller, which costs $295 (1000), and the ACB-5580 SCSI/SMD family, which ranges in price from $650 to $725 (1000). This family of controllers supports 10M- and 15M-bps rates and either single-ended or differential transceivers. Each product can handle four drives. The company also plans to offer a high-performance ESDI version this year.

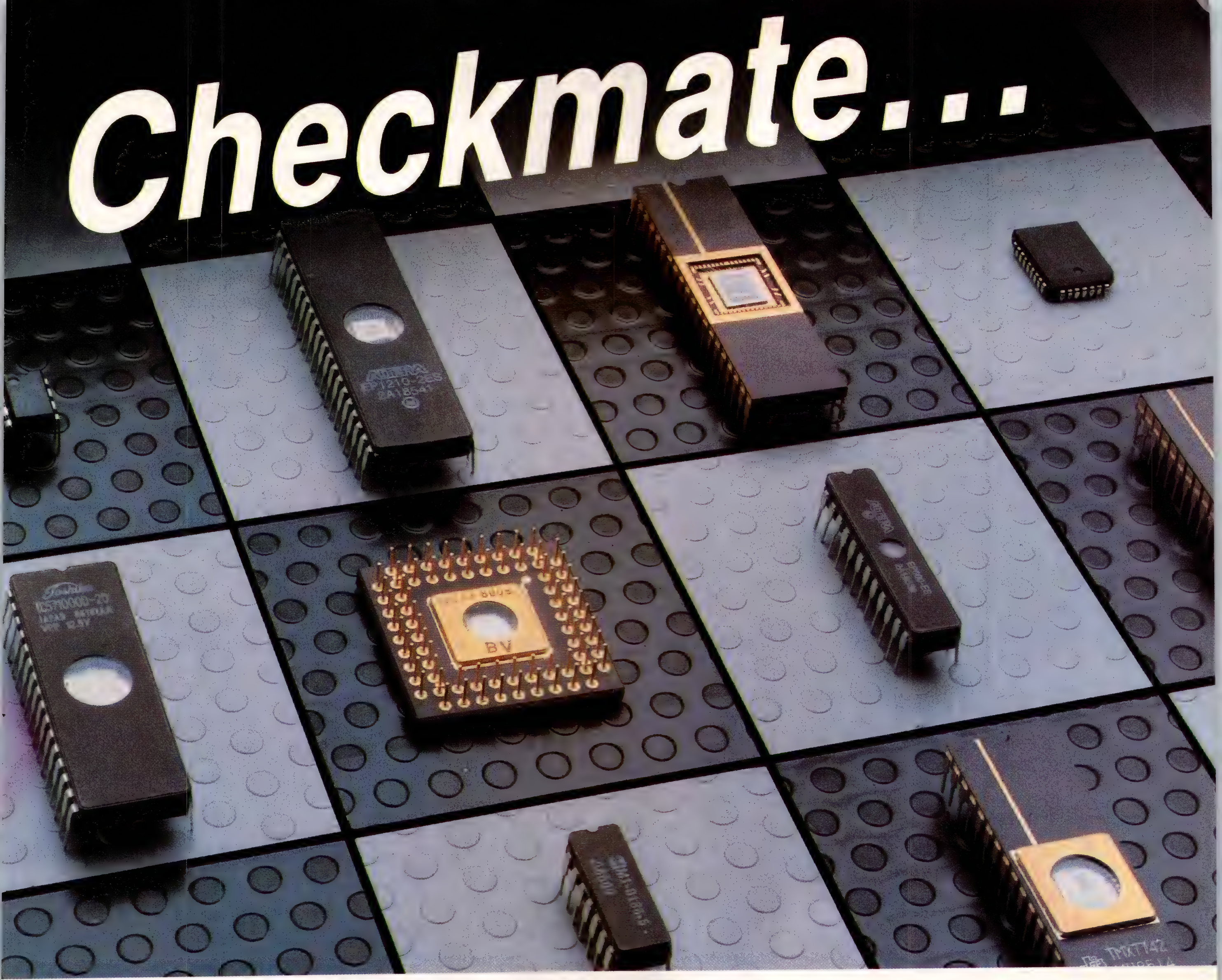
Jeff Miller points out that besides differing memory capacities and varying degrees of flexibility, bridged and embedded controllers also deviate tremendously in terms of overall system performance and cost. When comparing the system performance of the two types of controllers, you won't find clear-cut tradeoffs. You must take into account total system storage requirements and power and space considerations as well as cost and performance.

Multiple drives justify cost

From a cost standpoint, a bridged approach saves money when you have two or three drives connected to one controller compared with two or three embedded-SCSI drives. This is no longer always the case, however. Today you can buy 5¼-in. drives with capacities approaching one gigabyte, and therefore you may only need one drive.

From a performance standpoint at the system level, thanks to multithreading, multiple drives outperform a single drive. Multithreading refers to a computer essentially performing multitasking at the I/O subsystem level. A SCSI host can have multiple commands active within the I/O-bus subsystem simultaneously. And a SCSI/ESDI controller board can receive (and theoretically respond to) more than one command at a time. In fact, the top-of-the-line controllers from all the manufacturers discussed in this article support multithreading. Multithreading also enables controllers to link and queue commands for one or more disks.

In an I/O subsystem, the electromechanical head movement for seek operations causes the biggest bottleneck problem. By using multithreading techniques—essentially



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working on multiple commands at once—a controller can overlap the electromechanical-delay segments, called overlapped seeks.

Because of multithreading and overlapped seeking, you may be able to use multiple cheap drives with slow access times and get system performance equivalent to that of one expensive drive. Of course, multiple drives consume extra power, take up more space, and may still cost more. You must balance your choice of controller type and the number of drives depending on your application.

Multithreading at the SCSI I/O bus with embedded-SCSI drives provides the advantage of having a dedicated controller for each drive. Multithreading within a bridged controller, on the other hand, benefits from intimate ties to the hard-disk assemblies.

Controller prioritizes tasks

As SMS marketing manager Daniel Loski points out, a bridged controller can prioritize queued commands because it always knows the location of the disk heads. By prioritizing the tasks based on head location, the controller minimizes the electromechanical seek time.

When evaluating overall system performance and cost with your application (or applications) in mind, you should be aware that there are versatile boards available that support multiple interfaces. SMS's OMTI 7000 Series is such a line of controller boards. The basic OMTI 7100 SCSI controller can handle both ESDI and ST-506/412 drives, and it costs $164 (1000). Versions that include floppy-disk or tape interfaces, or both, are also available. For example, the OMTI 7400 includes a floppy-disk interface, a Winchester-disk interface, and a QIC-02 tape interface. It costs $330 (1000).

All 7000 Series boards include 32k-byte buffers, although you can buy 64k-byte versions, too. The series supports multithreading with two drives; the design will be expanded to support four drives this year.

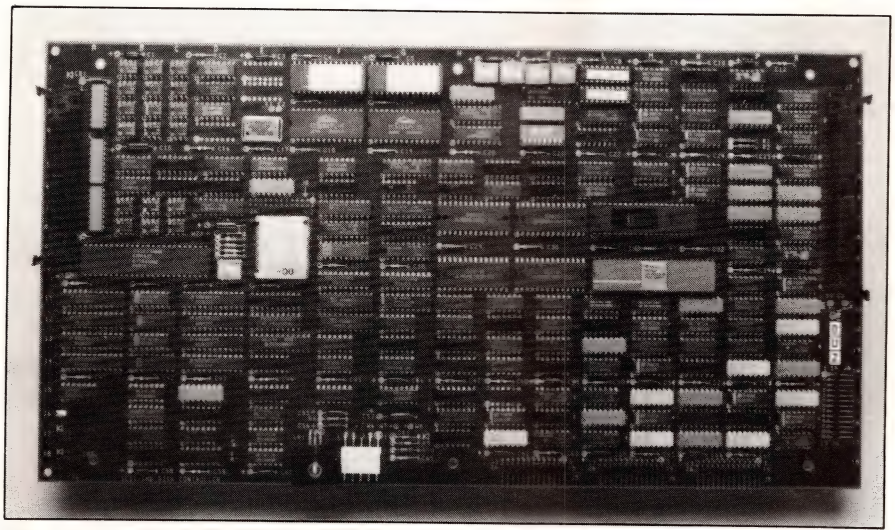
SMS is planning for the future also, which means selling bridged controllers for 3½-in. form factors. Compared with embedded controllers, stand-alone controllers offer advantages for 3½-in. products because embedded-drive manufacturers have even less pc-board real estate to work with. Available embedded-controller 3½-in. Winchester disks include only a basic controller. Both the OMTI 3520 and the 3527 fit in the 3½-in. form factor. The 3520 with MFM encoding supports ST-506 drives and costs $119; the 3527 RLL version sells for $134 (1000).

NCR also makes a SCSI/ST-506 controller in the 3½-in. size, and it even manufactures a SCSI/ESDI controller in the same size. You can actually specify the ADP-46 ST-506 model or the ADP-47 ESDI model in 3½- or 5¼-in. packages. Both of the 3½-in. packaged controllers sells for less than $200 (1000); the 5¼-in. versions are priced at less than $250 (1000).

Both of the controller boards operate at 2M bytes/sec asynchronously over the SCSI bus, and they handle four drives. The ESDI model runs with 15M-bps drives, and the ST-506 model employs MFM recording. For the 5¼-in. controllers, NCR includes a floppy-disk interface and differential transceivers.

Another controller, the NCR ADP-48—$1077 (1000)—provides a high-performance SCSI/SMD interface. In fact, the controller can handle four drives at maximum speeds of 24M bps. It operates at 3M bytes/sec synchronously over the SCSI bus and includes a 32k-byte buffer.

Controllers such as the ADP-48 provide performance levels approaching the upper end achievable without resorting to some type of caching controller. The SCSI bus, however, does fit in applications that can use more I/O performance. For such applications you have to use a bridged controller. Some embedded-Winchester controllers offer small caches, but they depend on the fact that the application software requires sequential data from the disk.



The SCSI/SMD ADP-48 controller *from NCR has a 32k-byte buffer and handles four disks.*

Cache hits eliminate seeks

If you need improved I/O performance, Distributed Processing Technology (DPT) offers true caching controllers for the SCSI bus. The PM3010/50 serves ST-506/412 drives and costs less than $700 (1000). The PM3010/70 ESDI version costs less than $900 (1000), and the SCSI/SMD PM3010/10 costs less than $1000 (1000). Each product can

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Record Length	4K/1K (selectable)	4K
Save Reference Memory	One, 4K Three, 1K	One, 4K
Vertical Resolution	8 bits 10 bits (AVG mode) 12 bits (AVG mode over bus)	8 bits
CRT Readout	Yes	No
Cursor Measurements	Yes (storage mode)	No
GPIB/RS-232-C Options	Yes ($850)	Yes ($550)
Battery-Backed Memory (save 26 waveform sets)	Yes (inc. with 2230 communications options)	No
Price	$5150	$4150

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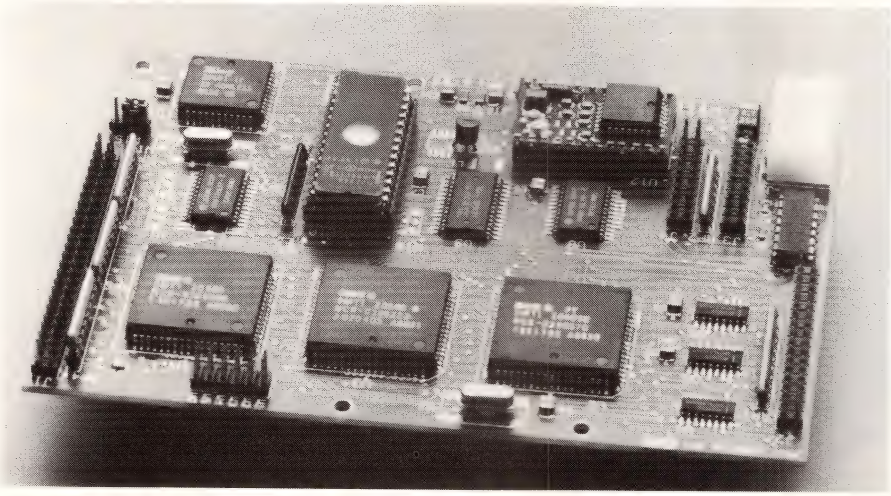

Intended for 3½-in. SCSI/ST-506 applications, *the SMS OMTI 3000 Series includes controllers that use MFM or 2,7 RLL encoding schemes.*

control four drives, and the ESDI and SMD models operate at 20M-bps device rates.

The controller boards offer a standard cache of 500k bytes; you can buy 2M to 16M bytes of expansion memory. According to company president Steve Goldman, the average customer adds 4M bytes of memory, and this expansion costs less than $1200 (1000). The 3010 family supports 1.5M-byte/sec SCSI transfers. The company plans to announce the 3015 controller around mid-year, which will be similarly priced, but will include synchronous capabilities.

These caching controllers operate with a least recently used (LRU) algorithm. The controller checks to see if the desired data is in the cache before accessing the disk. If a disk access is required, the controller flushes the least used data presently stored in the cache and replaces it with the requested data.

On cache hits, the controller typically begins transmitting data 500 μsec after receiving the last byte of the command. On misses, the drive must perform an average seek operation (18 to 20 msec) to find the data. Goldman claims that hit rates vary widely based on cache size and application, but he believes that, on the average, you will see a 30% performance improvement in your system with a caching controller.

The advantages and disadvantages of bridged controllers discussed thus far relate primarily to performance and price issues. Other general-purpose considerations may also influence your choice. For example, consider compatibility. All the controllers discussed here, and most embedded-SCSI Winchester controllers, meet the common command set (CCS). Although CCS has less options than SCSI, it doesn't eliminate them altogether. Moreover, any two drives may not plug into and operate with the same operating-system software.

Device-level interfaces, in particular ESDI, are more compatible than SCSI. By specifying a bridged controller, you can take advantage of device compatibility and easily locate second sources. Within a product family such as NCR's, Adaptec's, or SMS's, you can also specify bridged controllers for different device interfaces that function identically at the SCSI interface.

A final point to keep in mind is that the present SCSI spec limits a system to eight nodes. With prospects of having multiple hosts, LANs, printers, optical media, disk, and tape on one SCSI bus, you may be forced to connect multiple devices through one controller.

EDN

For more information . . .

For more information on the SCSI controller boards discussed in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

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Western Digital Corp
2445 McCabe Way
Irvine, CA 92714
(714) 863-0102
Circle No 724

References

1. Wright, Maury, "SCSI ICs simplify I/O-bus configurations, but options entail extra design effort," *EDN*, September 18, 1986, pg 97.

2. Wright, Maury, "SCSI host-adapter boards meet the needs of Multibus and VME Bus computer systems," *EDN*, October 16, 1986, pg 81.

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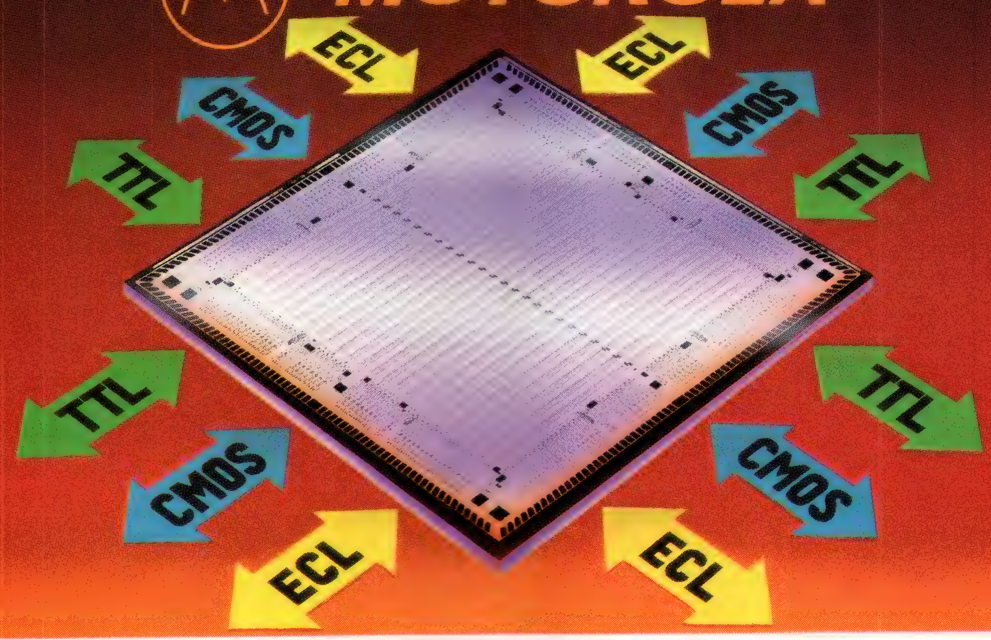

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- **Input translator/buffer delays (typ)**—
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- **Internal gate delays, 2-input NAND**—
  F.O.=1, 0 mm metal—0.8 ns
  F.O.=5, 2 mm metal—1.2 ns
- **Delay deg. per unit load**—275 ps/pF
- **Output translator/buffer delays (typ)**—
  TTL 8 mA @ 50 pF load—5.5 ns
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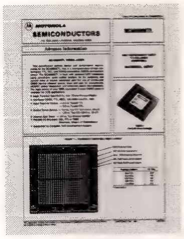

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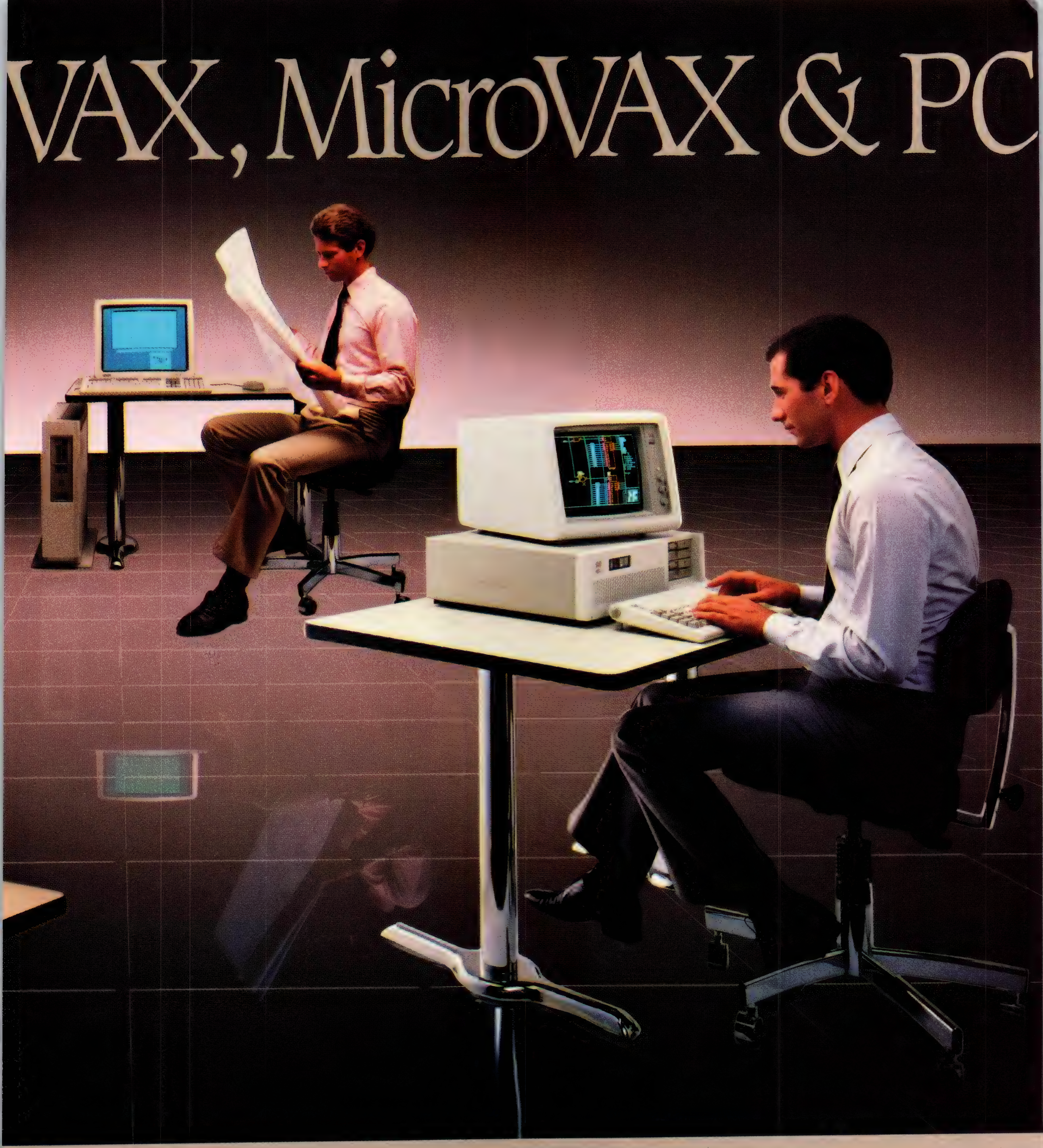

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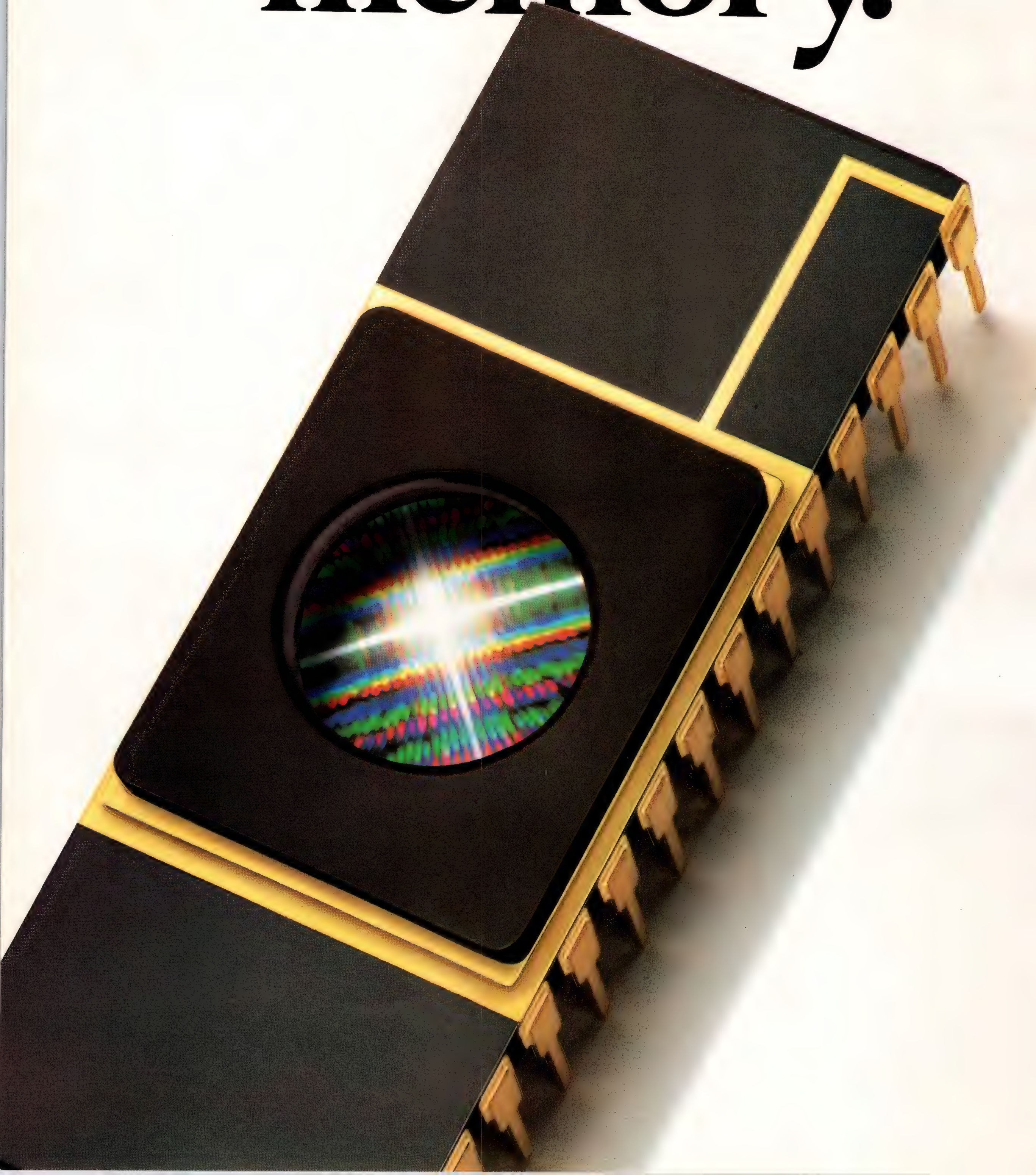

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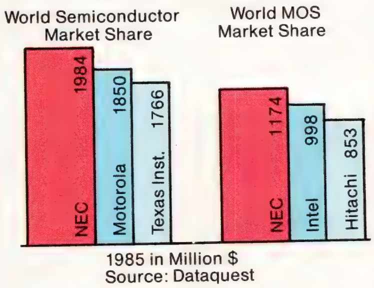

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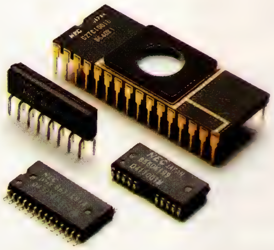

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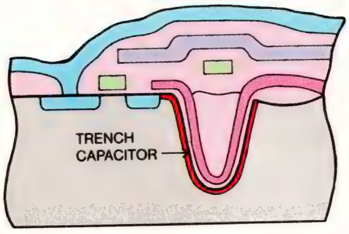

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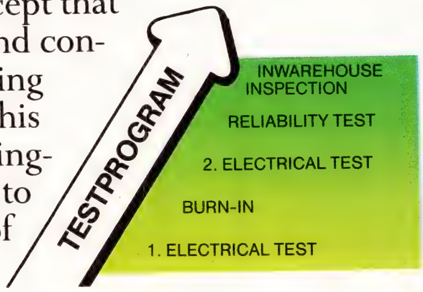

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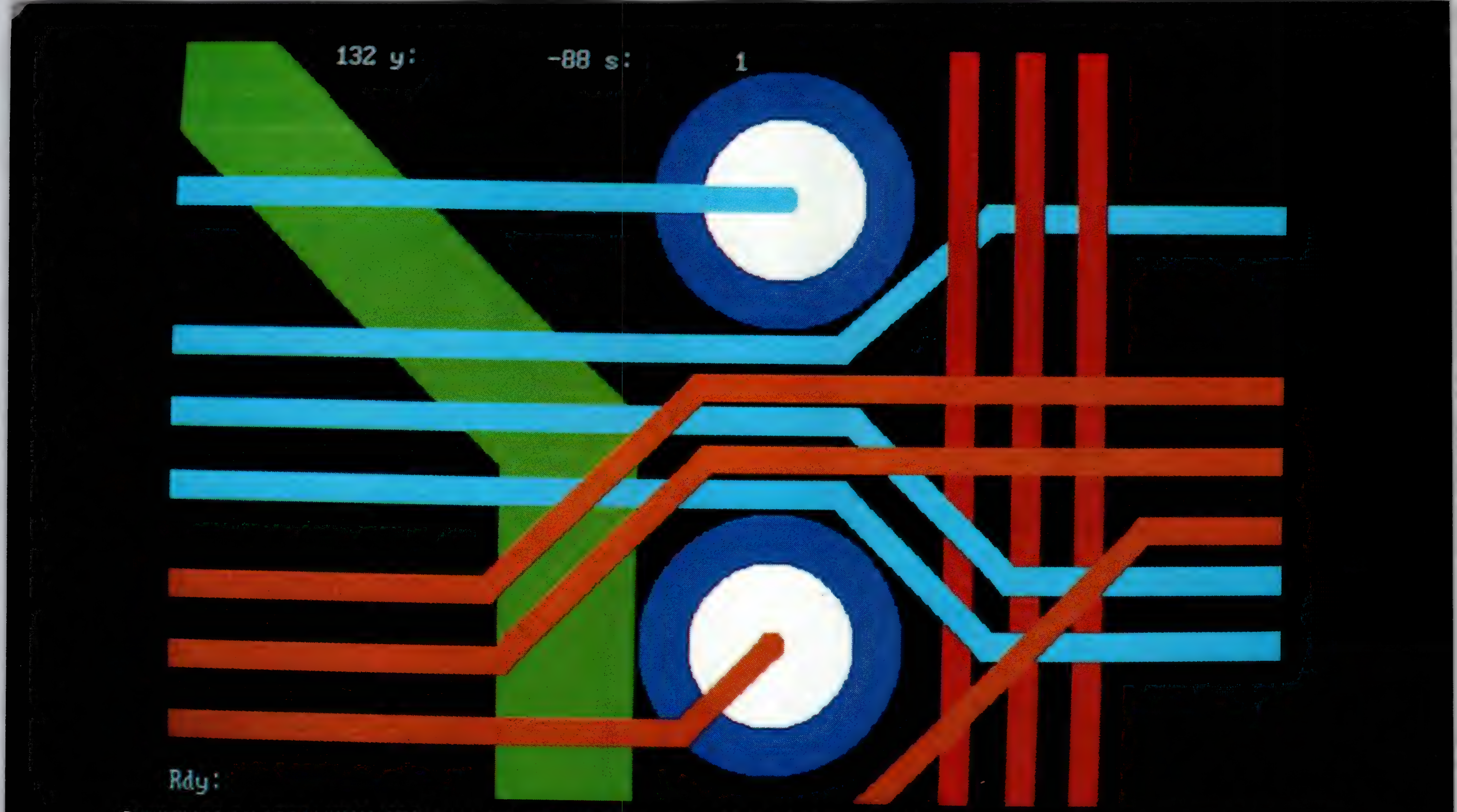

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Artificial-intelligence techniques boost utility of CAE/CAD tools

J D Mosley, *Regional Editor*

Artificial intelligence has found a valuable niche in computer-aided engineering and computer-aided design. CAE/CAD tasks frequently require the use of heuristics, and the application of AI techniques can reduce uncertainty by offering software-based inferential reasoning capability.

Yet the effects of AI in the engineer's work place are currently more evolutionary in nature than they are revolutionary. For example, no full-fledged intelligent CAE package has yet entered the market —you'll find only traditional CAE software that borrows techniques developed from AI research. However, as CAE software developers increase their AI expertise, you can expect increasingly more sophisticated CAE/CAD packages and, eventually, an expert system that provides innovative CAE/CAD solutions.

Identify applicable tasks

Although it is often difficult to distinguish between software that does and doesn't incorporate AI techniques, it is easy to identify engineering tasks that would lend themselves to AI solutions. Brian Horsley, senior engineer and AI systems specialist at PA Technology, cites pc-board routing as a classic problem for AI to tackle. Routing involves sifting through several outcomes, all of which are technically correct, in search of the best solution.

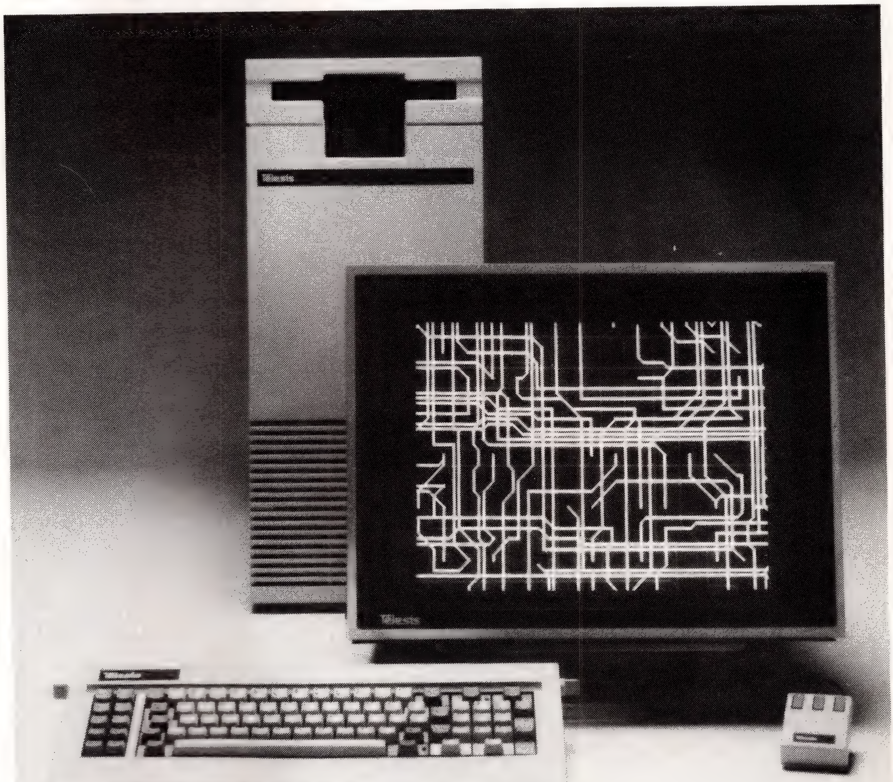
Instead of yielding to the clear-cut answers that computers generate when using analytical techniques, routing problems must be solved by comparing degrees of efficiency. An AI approach employs certain heuristics and facts to reduce the number of likely routes, thus streamlining the computer's search for optimal routing.

Significantly, the strategy (that is, inference engine) used to guide the computer through selection of the various heuristics and facts (often embodied in a set of design rules) must be independent of the knowledge base that contains the heuristics, rules, and facts. In this way, a change in circumstance or parameters will result in a revised application of the contents of the knowledge base. This flexibility differentiates an intelligent system from an algorithmic one.

Other focal areas for intelligent CAE packages include component layout, troubleshooting, and logic simulation: key areas where the benefits of balancing heuristic and theoretical knowledge significantly reduce the amount of time an engineer must devote to a design effort. But the state of the art at most major CAE companies has not yet spawned a classically defined, commercially available AI-based CAE system.

Expert system routes pc boards

Nevertheless, Telesis Systems Corp has announced a rule-based expert-system pc-board router,



Developed in Prolog as a conventional expert system for routing pc boards, *Insight analyzes your board's physical characteristics and your stipulated design rules to optimize routing strategy. The system is part of the Telesis EDA-3000 pc-board design software that runs on an EDA-300 or EDA-700 design workstation and EDA-620 routing accelerator.*

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called Insight, that analyzes the physical data and design rules necessary to develop and optimize routing strategy. After you enter English descriptions of the board's physical characteristics and design rules regarding such aspects as line width, spacing, and pad description, Insight accesses its database of routing techniques to create the unique set of routing instructions that yields the highest possible completion rates for the board you've described. Insight considers nearly 30 costing factors and automatically routes boards with as many as 14 signal layers.

Insight was developed in Prolog, a programming language used extensively in AI research but has been ported to C for increased speed and portability. The manufacturer claims that Insight's multipass, multialgorithm system outperforms rip-up routers by a factor of 10:1. You can use Insight for any design technology, including digital, analog, SMD, fine-line, and ECL. Moreover, you can specify grid resolutions as fine as 1 mil, any number of pad shapes and sizes, and an unlimited number of nets, connections, or components.

The system supports automatic on-line 45° routing. You can restrict routing and etching to particular areas of the board. Insight routes the horizontal traces first, followed by vertical traces, inserting vias only where needed. The Insight router is a module within the Telesis EDA-3000 PCB Design Application software, which costs $17,500. The EDA-3000 package includes schematic design, automatic placement, and the Insight router.

The embedded intelligence

Tektronix, on the other hand, has proven that AI techniques needn't be apparent to the end user to be useful. Instead of exposing gate-array design engineers to a foundry's reference database, Tektronix uses a rule-based expert system to conciliate each designer's goals with the foundry's manufacturing constraints. Merlyn-G, Tektronix's automated gate-array layout system, can literally apply any of hundreds of processing options to modify its design strategy when laying out a difficult gate array. Accordingly, it takes a significant amount of expertise to decide which Merlyn-G processing option to apply for the best design.

To provide this expertise, Tektronix developed software modules called TurnChips to tune the Merlyn-G controls for placement and routing (without intervention from the designer) while simultaneously producing a physical design that is functionally equivalent to one reproducible at the foundry's design center. Each foundry-endorsed TurnChip uniquely addresses a particular style of gate array. And it is in the development of each TurnChip that Tektronix's patented AI techniques are used.

TurnChip modules rely on rules concerning tuning decisions and control options to control the execution of programs during the layout process. However, when Tektronix tried to implement the design rules via an interpreter, the system spent more time deciding which program to execute than it took to run the program. So the company developed (and subsequently patented) a compiler for the rule base, which lets the TurnChip provide rapid batch processing by branching from one Merlyn-G program to another.

For engineers who know their equipment better than anyone else, an expert system shell called IN-ATE from Automated Reasoning Corp offers a simple way to generate a customized automatic test system for fault diagnosis. You define the unit under test (UUT) to the system by drawing a schematic diagram of the equipment with a mouse. The schematic includes a hierarchical structure and modular substructure of the UUT, connections between modules of the UUT, and accessable test points. IN-ATE saves the symbolic description of the UUT in a Lisp-format ASCII text file. No other information is required by IN-ATE; the system can automatically learn any other information it requires, or you can add it incrementally.

IN-ATE helps you develop the system's rules via an editor that uses a series of on-screen, menu-like dialog boxes. At each step in the construction of a rule, the editor checks for consistency and correctness. The rules encompass heuristics for fault diagnosis, such as the probability of failure at a particular testpoint, the cost of performing a test, and preconditions that must exist before testing is recommended. Using deductive reasoning and logic modeling, IN-ATE can automatically generate any missing rules. The system also builds and maintains a statistical reliability database based on inductive reasoning relating to failure probabilities.

The learning algorithm

Even more impressive are the IN-ATE learning capabilities. A learning algorithm lets IN-ATE readjust its reliability database and its rules to account for reported UUT failures. The system also uses nonmonotonic logic to refocus and reorganize its internal beliefs about the fault location. IN-ATE can even interactively guide a novice user through each step of a troubleshooting session.

IN-ATE has been used by Northrop Corp for automated testing of avionics on its F-5 fighter. The system also provides IEEE-488 bus support for computer-controllable test instruments. Procedural attachments let IN-ATE automatically program and activate test equipment. IN-ATE comes in several configurations for use with the Macintosh, VAX, and TI's Explorer workstation; price varies from $5000 to more than $30,000.

The specialized test stations (one version costs between $350,000 and $450,000) sold by Teradyne for

VLSI in-circuit testing also incorporate an expert system to accurately isolate faults. The expert system analyzes test data using a set of diagnostic rules and knowledge about circuit topology. The system also includes the tests performed by the test station in its diagnostic analysis, including any relationships among nodes that are directly and indirectly involved in each test. If a failure so requires, the system will perform additional tests to clarify a failure condition. Once the system completes all the tests, the expert system eliminates spurious results and generates a repair message for each fault. The system can also produce a history of device failures and generate statistical fault summaries by node and by component.

Teradyne has used AI in its diagnostic systems for the past 10 years, but with the increasing complexity of analog circuits and the large number of active nodes that a test station confronts during a VLSI in-circuit test, the use of AI becomes critical. Each true fault that occurs on a board can create several other apparent faults. Successful device isolation isn't always possible on a heavily populated board. As a result, Teradyne has developed a hierarchical organization of rules that govern the diagnostic process using procedural, production, and table-based schemes to minimize diagnostic time and the amount of memory used to execute the diagnosis. The Teradyne system uses both forward chaining and backward reasoning to arrive at a suitable fault diagnosis.

An overview of Teradyne's diagnostic system and the interactions among the various components in the system are illustrated in **Fig 1**. Notice that once the knowledge base obtains the test results from the test analyzer, the inference engine has access to information from every area in the system. Note also that the inference engine can also provide data to certain databases in the system. As soon as a fault has been identified, the system modifies the knowledge database so that the inference engine can use the new data to evaluate the remaining faults.

Although most expert systems designed for electronic engineering fall neatly into the traditional CAE/CAD formats, one of the oldest and most useful expert systems solves theoretical and applied mathematical problems. Originally developed in Lisp in the late 1960s at MIT, Macsyma represents over 100 man-years and more than 100,000 lines of source code. More than 600 technical papers have referenced Macsyma, which is described as both a programming language and an interactive system.

Since 1982, Symbolics has supported and enhanced Macsyma for use on four manufacturers' computers: DEC's VAX 11/7XX, Sun Microsystems' Sun-2 and Sun-3, Masscomp's MC5500, and Symbolics's 3600 Series. Price ranges from $6000 to $60,000.

Macsyma uses a library of symbolic math techniques to solve differential equations; to compute Laplace and inverse Laplace transformations; to factor polynomials; to simplify expressions; to compute Poisson series; and to generate Fortran statements from Macsyma expressions. It also uses the techniques to compute definite and indefinite integrals symbolically; to manipulate matrices, vectors, and tensors; to compute indefinite summations; to plot curves and surfaces; and to translate programs into Lisp

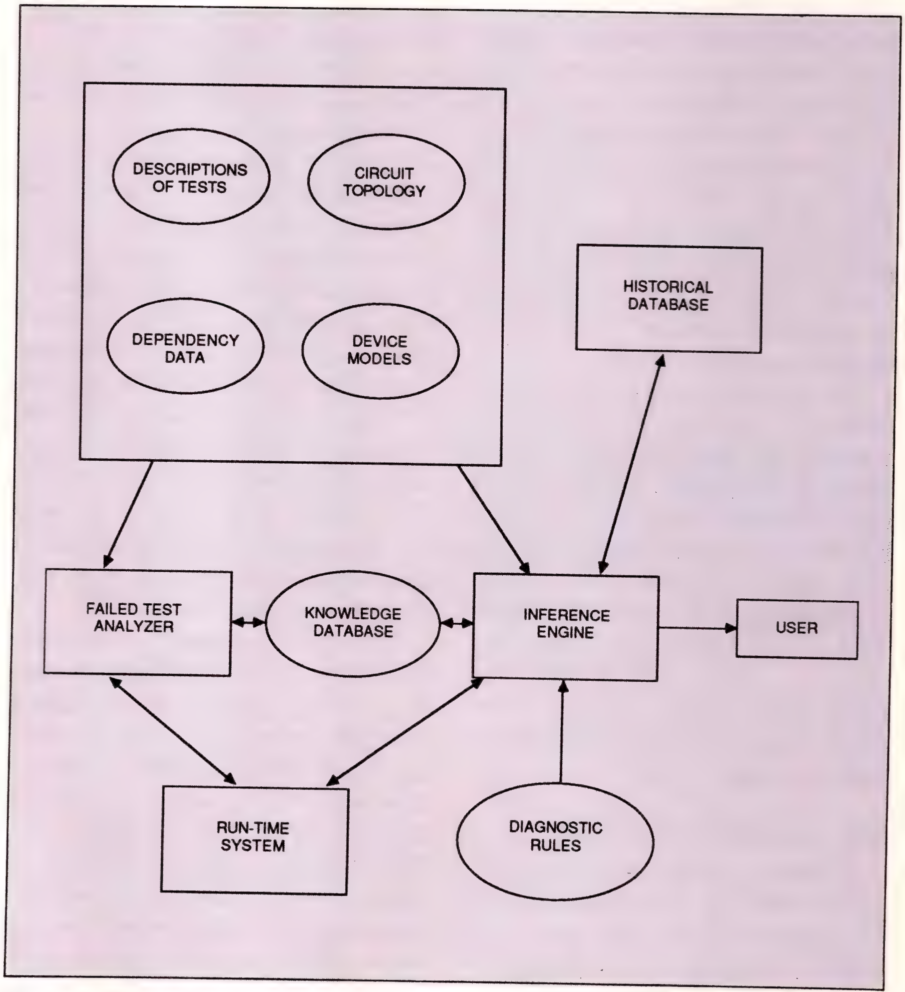

Fig 1—A diagnostic expert system *from Teradyne incorporates a number of interactions among the various system components. Note that the inference engine has access to information throughout the system and can also provide data to certain databases in the system.*

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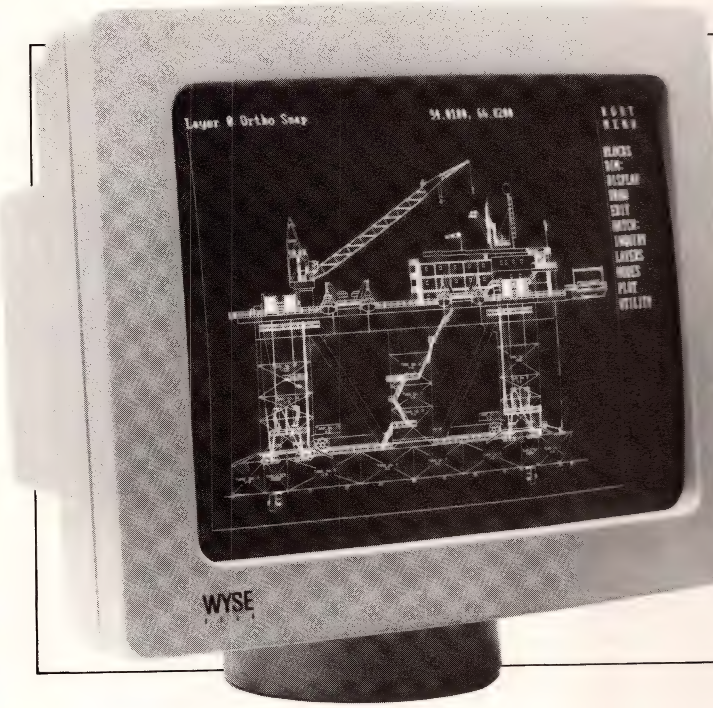

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for later compilation. And Macsyma provides answers in symbolic form, as a graph, or in Fortran code. Useful applications for EEs include VLSI design, analysis of electromagnetic fields and interference, and control theory.

But if you're faced with IC design choices that are of a more fundamental nature, you might want to consider a consultation with VLSI Technology's Design Assistant. This expert system helps you weigh the numerous tradeoffs that must be resolved before designing any complex IC. For example, Design Assistant can compare gate arrays versus cell-based implementation or custom design. It can evaluate partitioning alternatives and the maximum number of elements that you should squeeze into one chip. It even offers suggestions about the type of packaging you should use. Other interesting functions include estimation of chip size and power consumption.

Design Assistant performs these analyses even before you have completed your design. Or you can use the system to provide "what if" analysis before you actually begin your design. To facilitate system

For more information . . .

For more information on the CAE systems described in this article, contact the following manufacturers directly or circle the appropriate number on the Information Retrieval Service card.

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conception and to help document your alternatives, the system lets you enter block diagrams with data that describes your design. You can also enter data as gate count, a list of TTL parts, or a captured net list. Naturally, the accuracy of Design Assistant's recommendations improves with the accuracy of the design details.

Currently available only in VLSI Technology design centers, the Design Assistant will be released for use on VAX, MicroVAX, Apollo, Elxsi, Ridge, HP 9000 Series 320, and Sun computers as an integrated part of VLSI Technology's IC design system in the second quarter of 1987. Pricing for the Design Assistant module will be $25,000. The VLSI IC design software varies in price from $20,000 to $140,000.

Notably, not every useful CAE/CAD package that is advertised as an expert system actually uses traditional AI techniques. AI and expert systems are the latest buzzwords for fashionable software, and many companies may stretch traditional AI definitions to gain attention for their products.

Logic Automation provides extensive board-level logic simulation via software modules called SmartModels that encompass the behavior and characteristics of more than 1000 components—including memories, μPs, PLDs, and ALUs. Although device simulation is commonly used in IC design, board- and system-level designs are typically developed by breadboarding the circuit and then fine-tuning the design during multiple prototype phases. However, the complexity of many board-level devices is increasing to such a degree that simulation has become a necessary tool for designing sophisticated pc boards.

SmartModels are written at the behavioral level, giving them speed and functionality advantages over models developed by other companies using a gate-level approach. Some of the latest models offered by the company include Intel's 80386, IBM's CMAC—a complex number multiplier/accumulator, and TRW's TVC341 4-port memory. Prices for the company's models range from $400 to $5000, with special packages of multiple models costing as much as $25,500.

SmartModels include a symbolic hardware troubleshooting mechanism called Symbolic Hardware Debugging to identify design errors that can escape even prototype testing. As noted by Robert Hunter, marketing vice president, "The I/O protocols of the IBM CMAC, for example, are so complex that it will be virtually impossible to design with it successfully without simulation."

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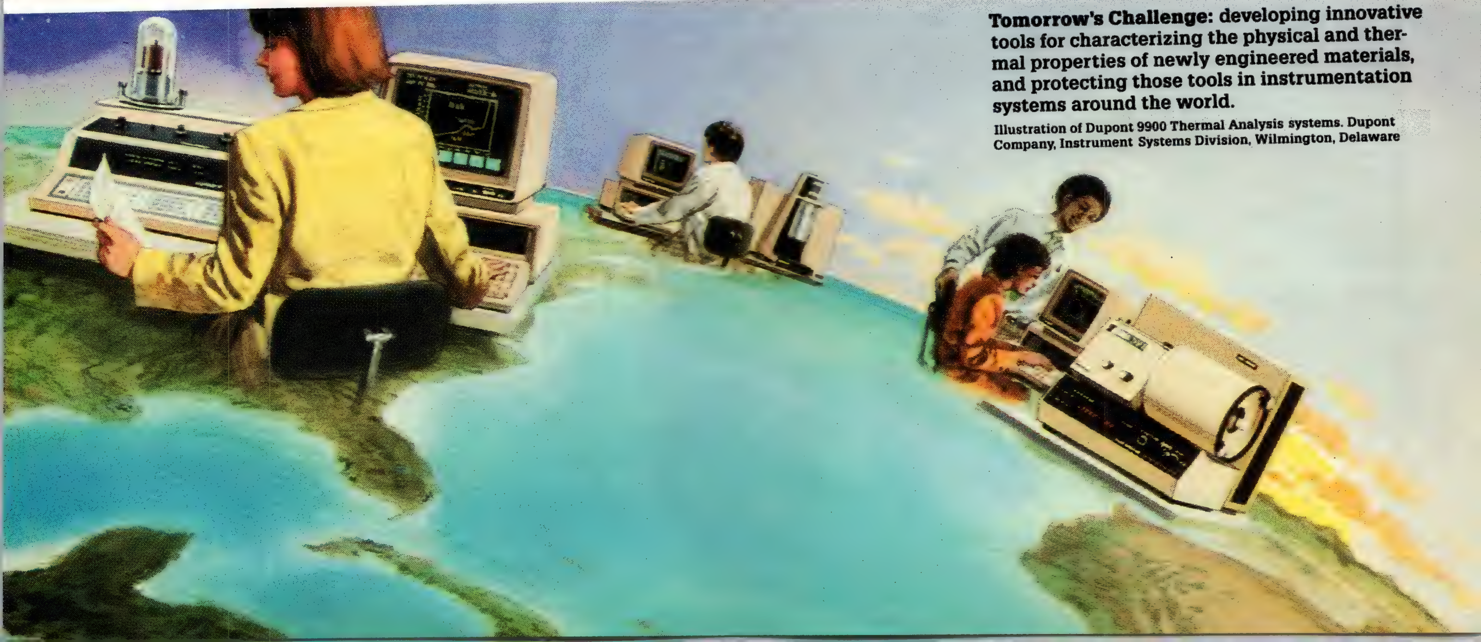

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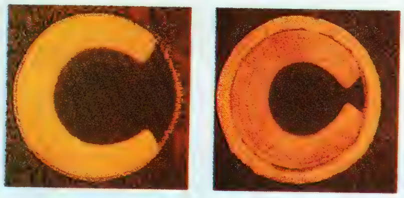

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UPDATE

Logic Automation uses experienced IC designers to develop these models. These designers determine from data books the kinds of problems a systems engineer is likely to encounter when using a part. They then write specific checks for these problems into the models to aid in design analysis. When an error occurs during simulation, the model issues a message stating the location, time, and nature of the problem.

It is therefore the Symbolic Hardware Debugging that encompasses the bulk of the expertise drawn upon for what Logic Automation refers to as "Knowledge Based Systems Analysis." The heading of a sidebar in the company's brochure even states that SmartModels actually turn your simulator into an expert system.

Yet, the company's current products do not actually provide inferential reasoning capability. Nor do they incorporate any type of AI-based machine-learning techniques. However, the sophistication of the design analysis offered by Symbolic Hardware Debugging does make them useful—though not AI-based—products. **EDN**

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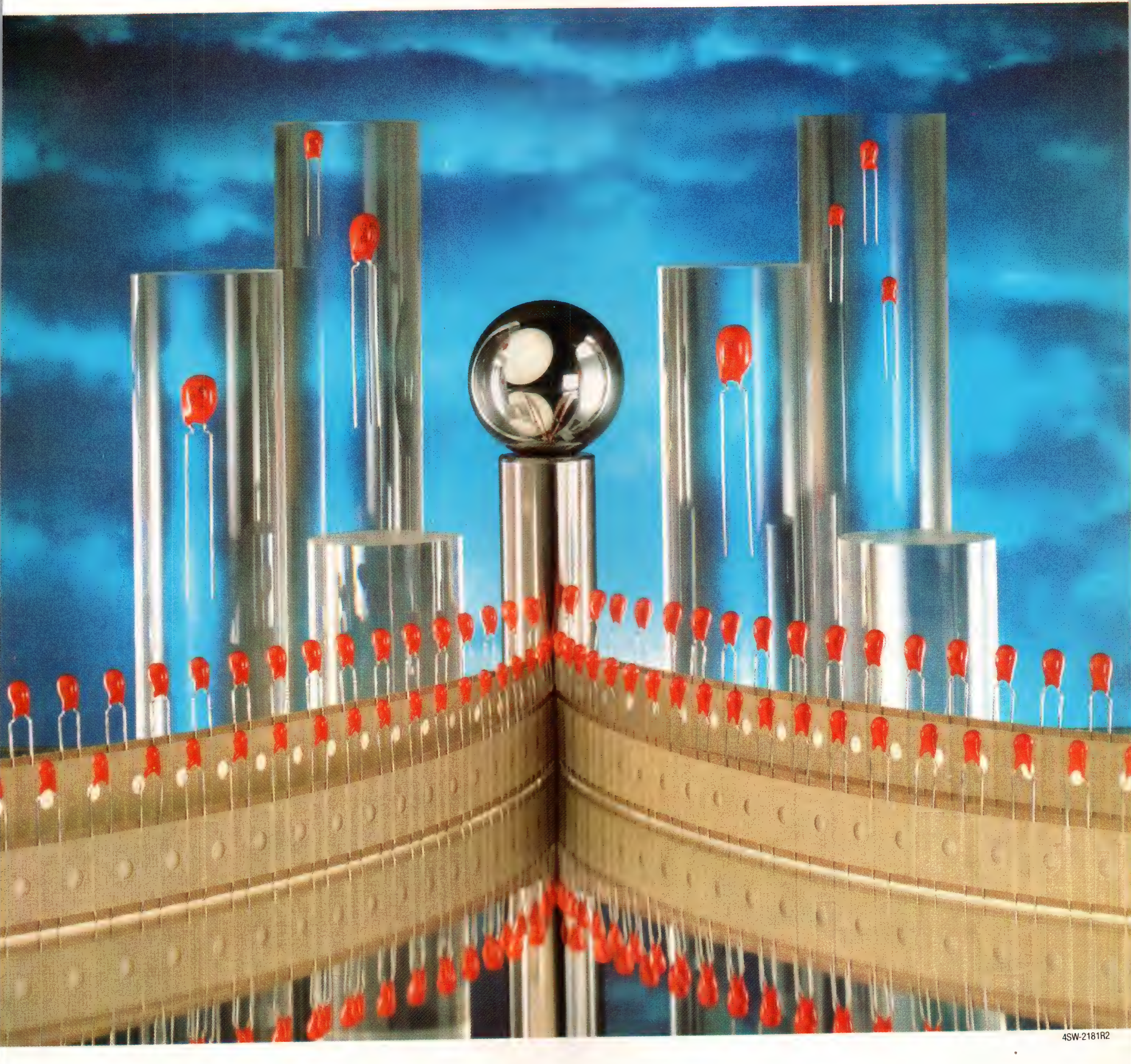

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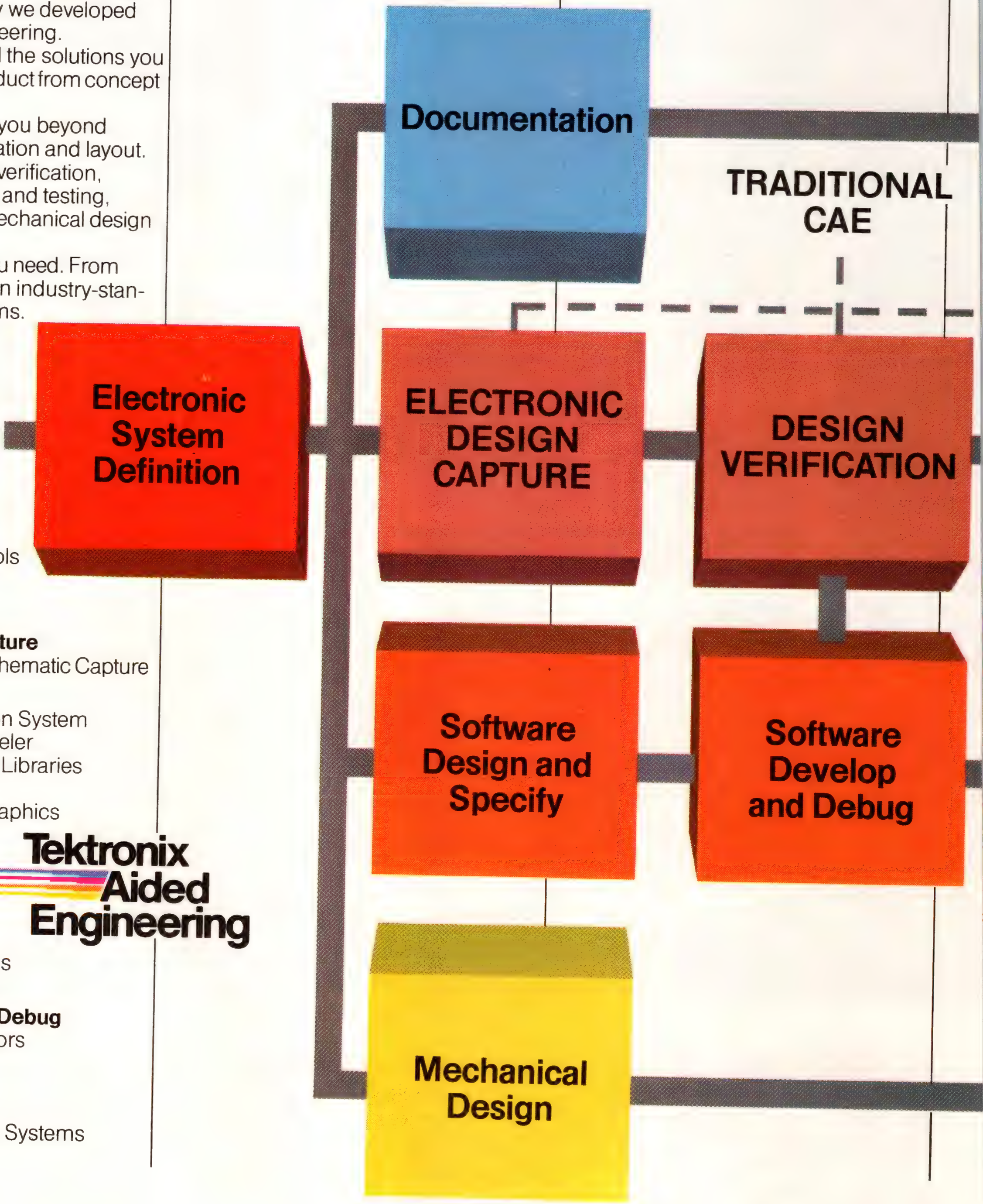
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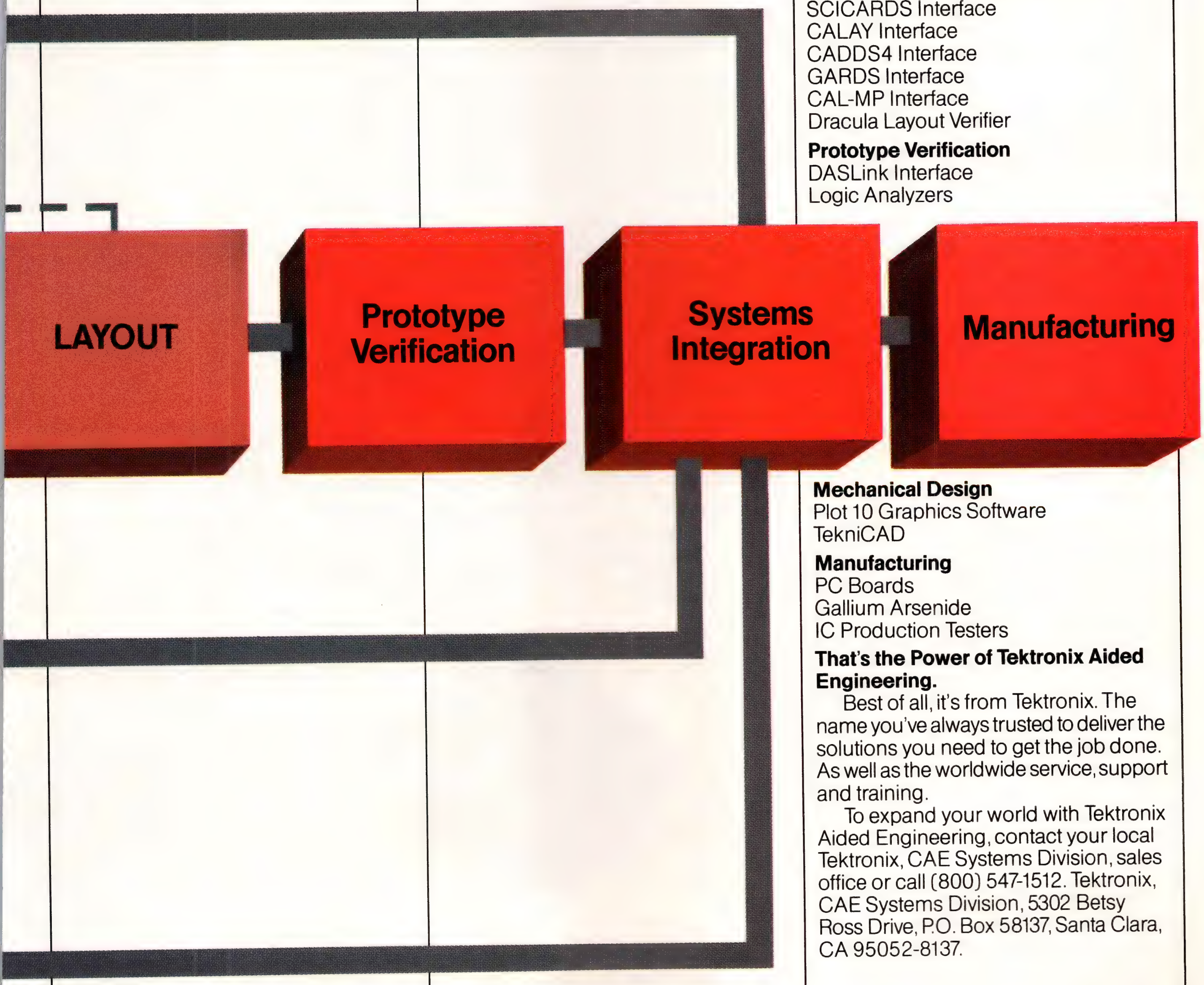

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That's right. Now you can add PC-AT functionality to your system by stuffing it with the PC on A Chip—or POACH CHIP, as we call it. Up to 25,000 gates. Another CMOS innovation from ZyMOS—the leader in SuperCell™ technology.

Actually it's two chips, that replace over 50 of the 96 devices (53%) on a PC-AT motherboard, including all the microprocessor peripherals*. Two chips freeing up all that board space. Now, what does that mean to you?

Among other things—you can improve the performance, functionality and cost of your board or system. And make it more reliable too! Since POACH is implemented in high speed CMOS, you can also expect a reduction in heat and power consumption. Imagine your system performing at 12 MHz!

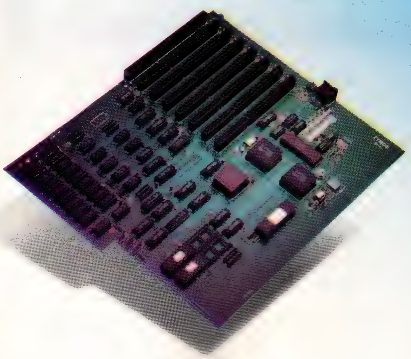
ZyMOS PCs on Chips are standard products so you can design them in fast. Getting your offerings to market—ahead of time. And ahead of your competition.

POACH Chip sets are only part of the story. Since they are implemented with cells from our SuperCell library, you can integrate any of your iAPX designs as we did the PC-AT. These cells are 100% functionally compatible with original off-the-shelf microprocessor peripherals they replicate. And can be interfaced to RAMs, ROMs, PLAs and other cells from our 1.8μ CMOS library.

Besides the POACH peripherals, our more complex SuperCells also include the 80C49 Microcontroller and the 29C01 4-bit Microprocessor Slice.

At ZyMOS, we support you all the way. We manufacture all our own parts, then guarantee them with our Zyp Silicon Level Simulator that assures your circuit design will perform as planned. And our FAEs are always ready to assist you.

Be there—ahead of time. Contact one of our local sales offices to check on the availability of the "right stuff". The POACH Chip Evaluation Kit. It includes the two chip set plus a surrogate motherboard. Put Big Blue compatibility in your black box now—and turn your competition green with envy.



POACH AT CMOS Peripherals

*8237A	DMA Controller
8254	Programmable Interval Timer
8259A	Programmable Interrupt Controller
8284	Clock Generator
82284	Clock Generator and Ready Interface
82288	Bus Controller
LS612	Memory Mapper
6818	Real-Time Clock/RAM

in your black box.

ZyMOS
Ahead of Time.

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477 North Mathilda Avenue
Sunnyvale, CA 94086
Phone: (408) 730-5400
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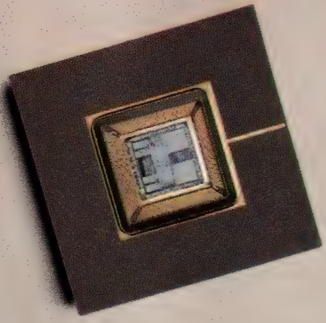
CIRCLE NO 71

IT'S A JUNGLE IN THERE.



Designing chips is like charting the unknown. You're better off with an experienced guide.

Like LSI Logic.

Our advanced ASIC approach gets you where you're going as easily as board level or TTL. But it lets you put so much logic into so little space, you may never want to rely on standard parts again.

It's simpler than you might expect, too, because our ASIC designs mean fewer components.

And fewer components mean fewer bugs.

And smaller footprints.

And smaller manufacturing costs.

But the best news is how fast we get you out of the jungle and into the silicon.

With software that will guide your designs into production the same way it has already guided more than 3000 others: with a 100% first-time hit rate. Guaranteed.

In as little as three weeks.

Go from 500 to 70,000 usable gates. On your own PC, workstation, mainframe or at any of our 30 design centers worldwide.

Where you'll get all the help you need to go from the drawing board to the assembly line.

You'll also get the optimum ASIC for the job, because you always have the optimum choice. From Gate Arrays, Compacted Arrays™ and Structured Arrays™ to Standard and Structured Cells™—the broadest product line in ASIC. All created with the same proven design methodology. And all processed in HCMOS technology.

Write to LSI Logic, 1551 McCarthy Blvd., MS D105, Milpitas, CA 95035 for your ASIC Starter Kit.

So the next time you have to trek across a blank CAD/CAM screen, you can do it with an experienced guide.

To the path of least resistance.

LSI LOGIC

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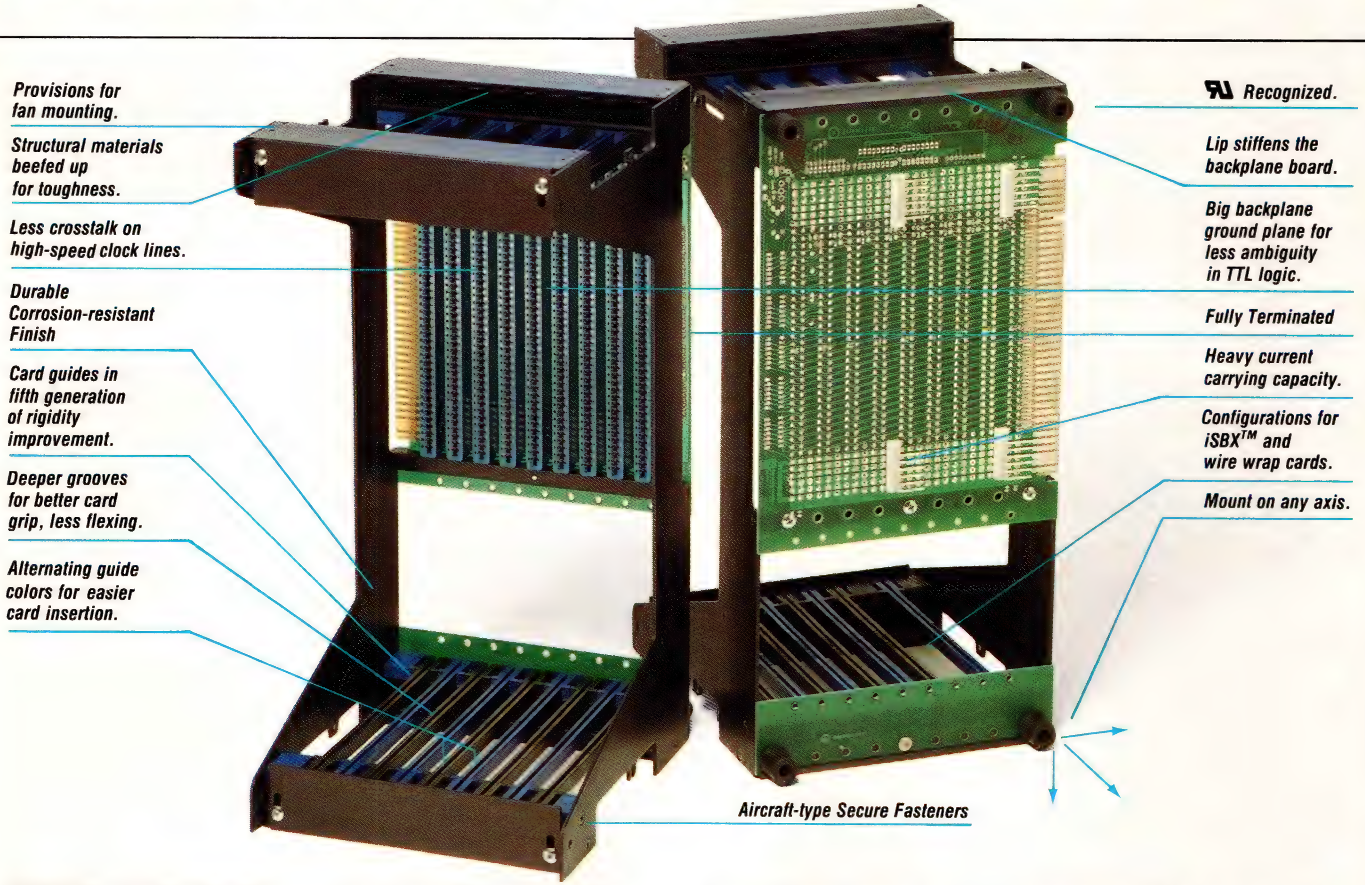
SEVENTH-GENERATION MULTI-CAGE® CARD CAGES

See What Our Eleven Years of Multibus Reliability Engineering Can Do for Yours.


Provisions for fan mounting.
Structural materials beefed up for toughness.
Less crosstalk on high-speed clock lines.
Durable Corrosion-resistant Finish
Card guides in fifth generation of rigidity improvement.
Deeper grooves for better card grip, less flexing.
Alternating guide colors for easier card insertion.
UL Recognized.
Lip stiffens the backplane board.
Big backplane ground plane for less ambiguity in TTL logic.
Fully Terminated
Heavy current carrying capacity.
Configurations for iSBX™ and wire wrap cards.
Mount on any axis.
Aircraft-type Secure Fasteners

Before you put your Multibus system packaging through the same rigorous engineering as the rest of your system, let us tell you about what's already been done.

When we designed and built our first Multibus card cage, the engineering was just beginning.

It was back in '76—generations ago as computer eras are measured. Electronic Solutions was a Multibus systems house. And Multibus was just beginning, too.

The card cage was the best around. So we put it into production.

And we've never stopped improving it since.

Today our Multi-Cage is the number one selling Multibus card cage. Because over the years it has been engineered and re-engineered to make your engineering job easier.

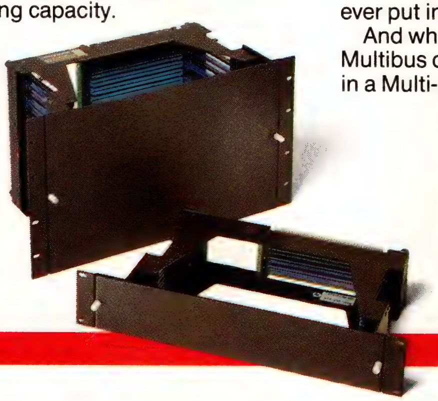
High-performance backplanes feature extensive ground planes that minimize crosstalk and improve TTL performance. Busing on both sides gives the backplane a large current carrying capacity.

Multi-Cages through an evolutionary process have been made more and more rigid. So cards stay put better under shock and vibration conditions. Special aircraft-type fasteners never loosen their grip. And the brushed anodized aluminum finish has developed into one of the most corrosion resistant ever put into a card cage.

And whatever you want in a Multibus card cage you can get in a Multi-Cage card cage.

Models with 3 to 26 slots. Configurations for iSBX and wirewrap cards. Free standing or horizontal or vertical rack mounting. You name it, you can have it.

Multi-Cage. We never stopped improving it. Because if the card cage isn't engineered right, your system won't be either. Dial our toll-free number today and ask for complete information.



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CIRCLE NO 73

16-bit VME Bus CPU module executes high-level languages directly

By implementing in hardware the stack-oriented virtual-machine environment that most high-level procedural languages operate in, the XVME616 16-bit VME Bus CPU module allows you to run high-level languages, such as Pascal or C, two to three times faster than code compiled for a conventional register-oriented µP. As a result, the CPU can eliminate the hand-coded, assembly-language program segments that you'd otherwise need in order to achieve sufficient processing speed for demanding real-time applications.

The XVME616's processor comprises an ALU with two separate 1024-word data and subroutine-return stacks. Minimizing the number of data transfers associated with each instruction, the data stack is closely coupled to the processor's ALU so that the ALU's operands, resident on the top of the data stack, are immediately available at the ALU inputs. The use of a separate subroutine-return stack, closely coupled to the program counter, provides a combined subroutine-call and -return instruction time of 400 nsec. The processor can context-switch between tasks in 5 µsec.

Because data is contained in a separate stack, local variables and subroutine operands maintain the same position in the data stack during subroutine-call and -return instructions, simplifying the code required for passing parameters between subroutines.

The XVME616's instruction set targets the execution of high-level languages, and it includes C and Forth language primitives. The processor is microprogrammed with 512 56-bit words of microcode that are contained in ROM, and most instructions execute in three or four clock cycles (150 to 200 nsec at the CPU's 20-MHz clock frequency). A C compiler will be available for the module this quarter, and the CPU's manufacturers will work with users to develop custom microcode for user-specific languages or applications.

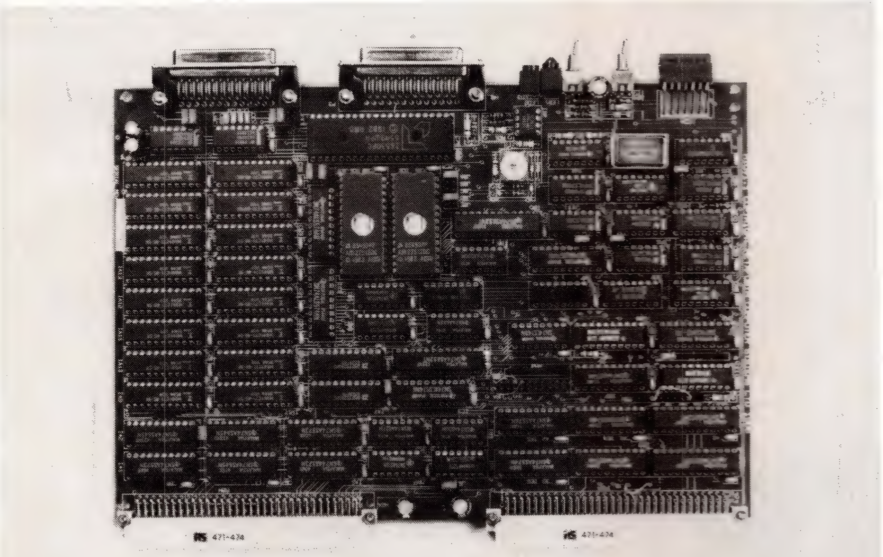
The board comes with an operating-system kernel, which, with the addition of an optional disk-controller board, provides a stand-alone program-development system for writing programs in C or Forth. The development-system software features a profiler that allows you to determine the proportion of total execution time occupied by various program segments. If you find that particular segments don't run fast enough, you can have high-speed application-specific instructions incorporated in the microcode.

The XVME616 comprises two double-Eurocard VME Bus boards mounted on a single front panel. Its onboard memory includes 128k bytes of static RAM, two 28-pin sockets for as much as 128k bytes of EPROM, and a boot ROM to load the operating system. Additional onboard facilities include two RS-232C serial ports, a real-time clock/timer, a watchdog timer, and a single-digit front-panel alphanumeric LED display. The CPU operates as an A24/D16 VME Bus master, and it includes a priority-interrupt handler for the seven VME Bus interrupt levels and for various onboard interrupt sources. The VME Bus interface also includes a single-level bus arbiter and bus time-out facilities. The XVME616 costs $3950.

—Peter Harold

Xycom Inc, 750 N Maple Rd, Saline, MI 48176. Phone (313) 429-4971.

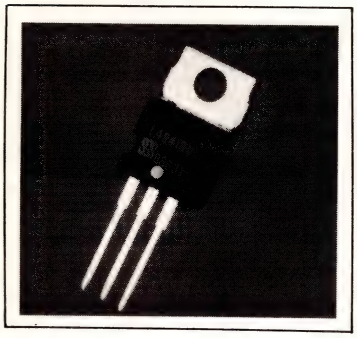
Circle No 726



Microcoded with instructions oriented toward the execution of high-level languages, *the XVME616 VME Bus CPU module targets real-time applications in which compiled code for conventional µPs won't run fast enough.*

READERS' CHOICE

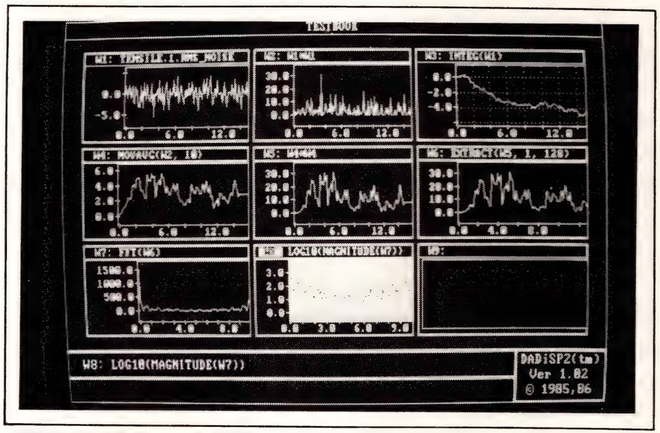
Of all the new products covered in EDN's **December 11, 1986,** issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, or refer to the indicated pages in our **December 11, 1986,** issue.



VOLTAGE ◀ REGULATOR

The L4941 5V/1A voltage regulator achieves a typical dropout-voltage rating of 450 mV (700 mV max) at full load and features a typical ground-pin current of 35 mA (50 mA max) at full load (pg 158).

SGS Microelettronica SpA.
Circle No 606
SGS Semiconductor Corp.
Circle No 607



SPREADSHEET ▲

Dadisp II provides post-acquisition data analysis in a spreadsheet format on IBM PCs and compatibles (pg 210).

DSP Systems.
Circle No 605

SEALED BATTERIES ▲

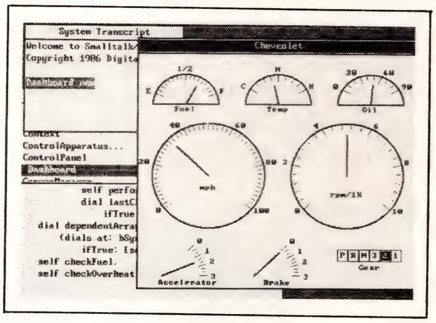
The SBS family of sealed lead-acid batteries comprises four models, the SBS 30, 40, 110, and 300, which provide 26, 35, 100, and 300 Ahr, respectively, at discharge rates of C/20 (pg 254).

Gates Energy Products Inc.
Circle No 604

LANGUAGE FOR PC ▶

Smalltalk/V is an implementation of the vendor's nongraphics version of this object-oriented programming language (pg 221).

Digitalk Inc.
Circle No 603



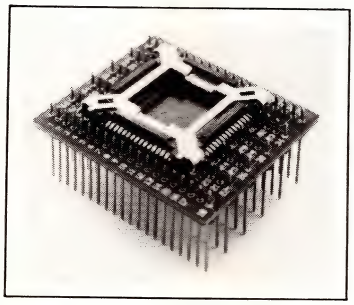
```
Welcome to Smalltalk/
Copyright 1986 Digita
```

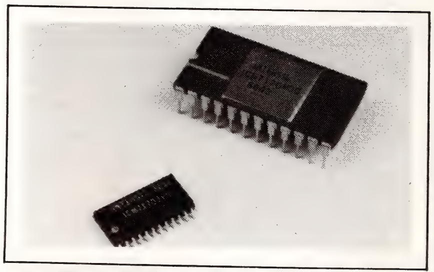
```
ControlApparatus...
ControlPanel
          self perfo
          dial lastC
              ifTrue
  dial dependentArra
      (dials at: bSy
          ifTrue: Is
  self checkFuel.
  self checkOverheat
```

ADAPTERS ▶

Series ANC-9068 and -9084 adapters let you wire-wrap prototypes of designs employing LCCs or pin-grid-array (PGA) devices (pg 108).

Antona Corp.
Circle No 602





▲ CLOCK/CALENDAR IC

The CMOS ICM7170 real-time clock chip furnishes either a 12- or 24-hour time in an 8-bit binary format over the military temperature range (−55 to +125°C) (pg 60).

GE/Intersil.
Circle No 601

"Sierra's
new power supplies
got VDE."

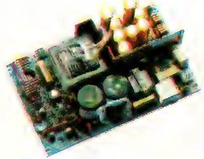
"Should they really
be talking about
something like that
in an ad?"

Why not?! From 45 to 500 watts, every open frame switching power supply in our new wide line meets VDE 0806 for safety. And all have a TUV logo on the side to show they've been approved to these precise VDE standards; not "designed to meet." Of course, none of this should surprise you. After all, every switcher we've introduced since 1983 meets VDE.

In addition, these power supplies all meet VDE 0871, Level A for conducted noise. Some even meet the more stringent Level B requirement, including the new "10 to 120KHz" standard.

Oh, since we got VDE, we figured we ought to get approvals for UL and CSA plus conform to FCC, IEC and other international regulatory agencies as well.

So if your product needs a power supply PDQ that meets VDE, UL, CSA, ETC., call ASAP. Sierra Power Systems (formerly Sierracin), 20500 Plummer Street, Chatsworth, California 91311. Call toll-free (800) 423-5569. In California, (818) 998-9873.



Sierra Power Systems
Division of Valor Electronics, Inc.

CIRCLE NO 74

LEADTIME INDEX

Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	0	25	59	8	8	0	8.8	8.1
Pot-Core	0	13	63	12	12	0	10.5	8.2
Laminate (power)	0	28	61	5	6	0	8.0	7.7
CONNECTORS								
Military panel	11	22	45	11	11	0	8.8	9.6
Flat/Cable	23	41	23	9	0	4	5.9	3.9
Multipin circular	0	21	43	36	0	0	9.6	8.9
PC	11	45	33	11	0	0	5.7	6.0
RF/Coaxial	17	50	17	16	0	0	5.4	4.4
Socket	23	53	12	12	0	0	4.4	4.7
Terminal blocks	12	47	29	12	0	0	5.6	4.2
Edge card	9	41	32	14	4	0	7.0	5.5
Subminiature	18	41	23	12	6	0	6.4	6.5
Rack & panel	10	50	20	20	0	0	6.2	5.8
Power	8	23	54	15	0	0	7.4	5.7
PRINTED CIRCUIT BOARDS								
Single-sided	0	65	35	0	0	0	4.8	5.4
Double-sided	0	30	70	0	0	0	6.5	4.3
Multilayer	0	18	65	13	4	0	8.9	7.2
Prototype	0	79	16	5	0	0	4.4	2.7
RESISTORS								
Carbon film	37	33	19	11	0	0	4.2	3.1
Carbon composition	35	38	19	8	0	0	3.9	5.4
Metal film	33	29	29	9	0	0	4.5	3.8
Metal oxide	25	33	42	0	0	0	4.3	5.6
Wirewound	43	43	14	0	0	0	2.4	6.4
Potentiometers	19	33	33	15	0	0	5.9	6.6
Networks	19	29	38	14	0	0	6.1	5.6
FUSES	43	43	14	0	0	0	2.4	3.0
SWITCHES								
Pushbutton	26	44	17	13	0	0	4.7	4.9
Rotary	10	45	35	10	0	0	5.7	5.3
Rocker	26	42	21	11	0	0	4.6	5.0
Thumbwheel	20	40	27	13	0	0	5.4	7.5
Snap action	36	46	9	9	0	0	3.5	4.5
Momentary	37	27	27	9	0	0	4.4	5.4
Dual in-line	20	60	10	10	0	0	4.2	5.5
WIRE AND CABLE								
Coaxial	50	44	6	0	0	0	1.8	3.6
Flat ribbon	59	32	9	0	0	0	1.7	3.6
Multiconductor	47	35	12	6	0	0	2.9	4.0
Hookup	58	38	4	0	0	0	1.5	1.7
Wire wrap	67	33	0	0	0	0	1.0	2.8
Power cords	20	48	28	4	0	0	4.3	4.4
Other	33	17	33	17	0	0	5.8	3.2
POWER SUPPLIES								
Switching	10	37	37	16	0	0	6.5	9.0
Linear	17	50	25	8	0	0	4.8	8.1
CIRCUIT BREAKERS	22	28	39	11	0	0	5.7	6.6
HEAT SINKS	35	35	24	6	0	0	3.9	4.3

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
RELAYS								
General purpose	32	21	37	10	0	0	5.2	6.5
PC board	10	32	32	21	5	0	8.1	8.3
Dry reed	8	33	42	17	0	0	6.9	10.0
Mercury	0	29	57	14	0	0	7.6	11.0
Solid state	8	31	31	23	7	0	8.9	8.2
DISCRETE SEMICONDUCTORS								
Diode	39	18	39	0	0	4	4.8	4.5
Zener	39	9	35	17	0	0	5.7	4.9
Thyristor	27	7	53	13	0	0	6.5	6.4
Small signal transistor	35	20	30	15	0	0	5.3	7.1
FET, MOS	13	20	53	7	7	0	7.6	7.8
Power, bipolar	15	39	46	0	0	0	4.8	4.5
INTEGRATED CIRCUITS, DIGITAL								
CMOS	23	31	27	15	4	0	6.4	7.6
TTL	26	22	39	9	0	4	6.5	4.7
LS	32	18	39	7	4	0	5.7	5.0
INTEGRATED CIRCUITS, LINEAR								
Communication/circuit	25	12	50	13	0	0	6.3	7.9
OP amplifier	10	37	37	16	0	0	6.5	8.0
Voltage regulator	14	33	34	19	0	0	6.6	6.8
MEMORY CIRCUITS								
RAM 16k	14	57	29	0	0	0	4.0	8.4
RAM 64k	17	50	33	0	0	0	4.2	6.7
RAM 256k	18	46	27	19	0	0	5.0	7.7
ROM/PROM	0	55	45	0	0	0	5.3	8.0
EPROM	14	41	27	14	0	4	6.9	7.3
EEPROM	8	31	46	8	0	7	8.2	8.3
DISPLAYS								
Panel meters	9	46	27	18	0	0	6.4	5.7
Fluorescent	0	29	43	14	14	0	10.1	10.0
Incandescent	0	75	25	0	0	0	4.3	9.3
LED	9	54	23	14	0	0	5.6	5.9
Liquid crystal	0	39	46	15	0	0	7.2	8.7
MICROPROCESSOR ICs								
8-bit	20	53	20	7	0	0	4.2	7.3
16-bit	20	70	10	0	0	0	2.9	8.2
FUNCTION PACKAGES								
Amplifier	0	63	37	0	0	0	4.9	8.3
Converter, analog to digital	0	39	38	15	8	0	8.6	10.8
Converter, digital to analog	0	40	40	10	10	0	8.5	10.7
LINE FILTERS	0	50	38	12	0	0	6.4	7.5
CAPACITORS								
Ceramic	23	41	21	15	0	0	5.2	4.9
Ceramic monolithic	20	40	25	15	0	0	5.5	5.4
Ceramic disc	27	31	27	15	0	0	5.5	5.6
Film	21	24	45	10	0	0	5.9	6.7
Electrolytic	19	37	18	26	0	0	6.6	6.3
Tantalum	15	37	26	22	0	0	6.6	7.2
INDUCTORS	8	38	54	0	0	0	5.5	8.6

Source: *Electronics Purchasing* magazine's survey of buyers

The world, as everyone knows, is analog.

Unless, of course, it's digital.

Seeing it both ways is the beauty of Intersil DSP.

Should they happen upon a perfect rose, most people will wisely stop, sample its beauty, and move on.

But there's a certain breed of engineer who won't let it go at that. They'll find themselves overwhelmed by the desire to "process" the experience.

In an instant, they'll have labeled the rich color and velvet texture as "analog signals."

From there, it's just a matter of time before they've transformed the rose into a repeatable, verifiable stream of digital bits.

They can then commit this information to the perfect memory of a digital computer. From which it can be recalled, and its image replicated, on a high resolution color monitor.

The engineer can now enhance the flower's image. Perhaps try a different color. Or add a few petals. He might even use his new database to create a species of his own. All these fantastic calculations and transformations are one example of the imaginative world of digital processing, or DSP.

In the last few years DSP has blossomed into one of the most exciting system design tools.

By moving from analog to digital processing of analog signals, engineers can overcome the drifts that plague analog circuitry. They can manipulate empirical data and explore engineering tradeoffs. And they can erect elaborate models using computer simulation.

But to do any of this effectively, the designer needs a DSP supplier who is comfortable in both the analog and digital worlds.

With over 17 years of analog leadership, and 20 years of corporate experience in DSP to draw upon, Intersil is uniquely qualified to work with the DSP engineer.

On the pages that follow, you'll see that Intersil, by taking an integrated approach to the DSP marketplace, has created your best, single source of complete DSP system solutions.

Anything's possible with Great Engineering.

A complete product family that's easy to get along with.

As we said, we're going to meet all the designer's needs. Obviously, that means we'll need new DSP products.

So we'll be introducing a family of ten new DSP parts in the months ahead. And we'll be bumping up the speed and resolution of our data converters, too.

Thanks to a $40 million GE investment in our fabs, these will be the most complex ICs in our history.

Using our new 1.3-micron AVLSI capability, we'll integrate over 100,000 transistors. And meet the toughest military standards with four DESC-certified fab lines.

One of our first new DSP parts is a CMOS FIR Filter, the IM29C128. And we're pretty proud of it.

It delivers ten times the performance of alternative products, and consumes less power.

Most remarkable, however, is how easy it is to work with.

Because along with the chip, we're releasing a new FIR Filter Development System. With it, and your IBM®-compatible PC, you can design a digital filter in a matter of hours.

Even if you have absolutely no digital experience.

This should give you an idea of the DSP excitement that you can expect from Intersil. To learn more call

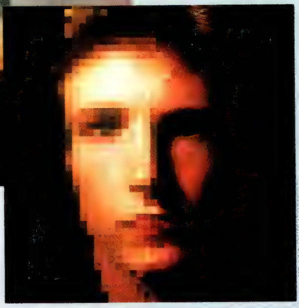
1-800-443-7364, ext. 777.
(In NY State, 1-800-243-7364, ext. 777.)

And be sure to ask about what else we've got coming. You'll find it's quite a bit of everything, from A to DSP.

For free on-line information dial 1-800-345-7335 (203-852-9201 in Connecticut) and follow the On-Line Instructions printed on the back.

INTERSIL

Intersil. Everything from A to DSP.



Every signal processing system has three elements: analog to digital conversion, digital processing and digital to analog conversion.

Knowing this, Intersil has taken the only logical approach to DSP: a complete, integrated system from a single supplier.

We intend to become the signal processing engineer's one-stop shop.

You might have expected this solution from Intersil. We've always chosen the systems approach to problems. Consider our work in instrumentation.

Working with instrument engineers, we've developed 17 families of "instruments on a chip." They perform all the functions for an instrument in a single CMOS part.

Given our history, you might also have expected that the DSP marketplace is very important to us.

After all, we've always worked in analog signal conditioning, data acquisition and data conversion. And we've integrated analog and digital functions on the same chip. A case in point is our monolithic 40-μSEC 14-bit ICL7115 A/D Converter.

So today, when our traditional analog customers are moving into DSP, it just makes sense for us to help them bridge the gap.

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ICL7151 10-Bit A/D Converter with Track and Hold
The ICL7151 is a 10-bit A/D converter that achieves throughput rates of 60kHz with Two-Step Flash algorithm. A pipelined operation has been achieved with a switched capacitor technique that allows the device to sample new input voltages while a conversion is taking place. The ICL7151 requires a single reference input of +2.5V, which is internally inverted to -2.5V, thereby allowing an input range of -2.5V to +2.5V. The reference input to the device is internally buffered by a high speed CMOS amplifier, which greatly simplifies the external analog drive requirements for the device. A track and hold amplifier has been fully integrated on the front end of the A/D converter. The timing signals for the track and hold amplifier are generated internally, and are also provided externally for synchronization purposes. The ICL7152 is a faster version of the ICL7151; it has a throughput rate of 200kHz.

IM29C128 Finite Impulse Response Filter Controller
The 16-bit FIR Filter Controller (FFC) provides all the data history, storage and programmable filter cycle control logic required to implement FIR filters of up to 128 filter points. When used in conjunction with an external filter coefficient memory, of up to 128 words by 16 bits, and an industry standard 16-bit Multiplier-Accumulator (MAC), the FFC provides the system designer with the ability to implement a powerful FIR filter with only three ICs. The FFC provides all the control signals required to operate the MAC and the coefficient memory as tri-stateable devices, allowing multiplexed usage of these resources.

IM29C510 CMOS 16 x 16-Bit Multiplier-Accumulator
The IM29C510 is a high speed 16 x 16-Bit Parallel Multiplier-Accumulator that operates at a 65ns clock rate (more than 15 MHz Multiply-Accumulate rate). The two input registers accept an x operand and a y operand and yield a full precision product. Built with Intersil's AVLSI 1.3-micron CMOS process, the IM29C510 16 x 16-Bit Multiplier-Accumulator is pin and function compatible with the same speed, at one-sixth or less power dissipation, as bipolar versions.

ICL7134 14-Bit Multiplying Microprocessor-Compatible D/A Converter
The ICL7134 combines a four-quadrant multiplying DAC using thin film resistor and CMOS circuitry with an on-chip EPROM-controlled correction circuit to achieve true 14-bit linearity without laser trimming.
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ICL7121 16-Bit Multiplying Microprocessor-Compatible D/A Converter
The ICL7121 achieves 0.0003% linearity without laser trimming by combining a four-quadrant multiplying DAC using thin film resistors with an on-chip EPROM-controlled correction circuit. Silicon-gate CMOS circuitry keeps the power dissipation very low. Microprocessor bus interfacing is eased by standard memory WRite cycle timing and control signal use. The input buffer register is loaded with the 16-bit input and direct controls the output switches. The register is transparent if WR and CS are held low.

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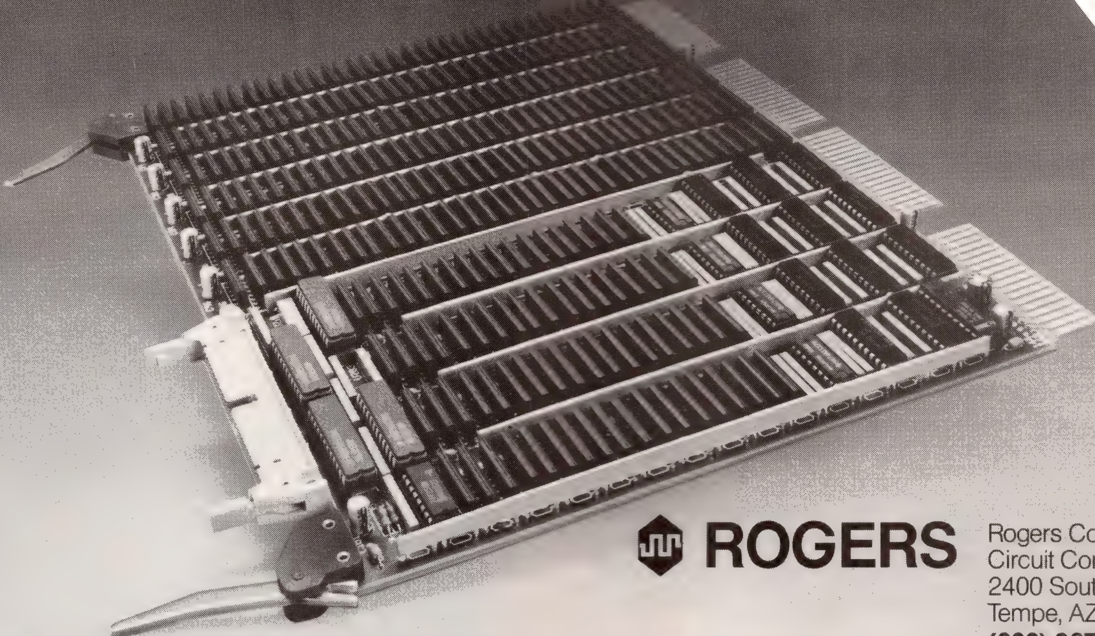

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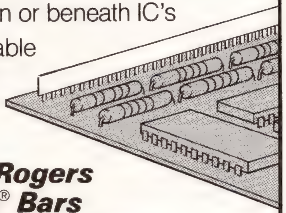

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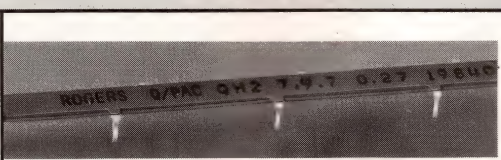

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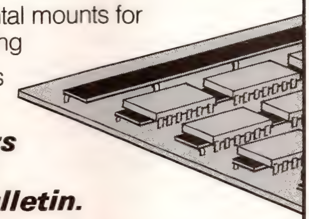

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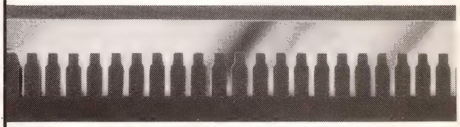

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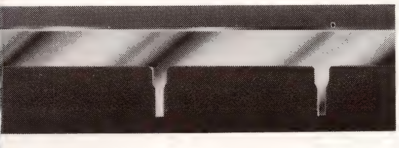

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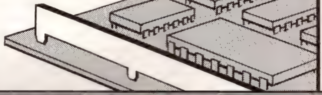

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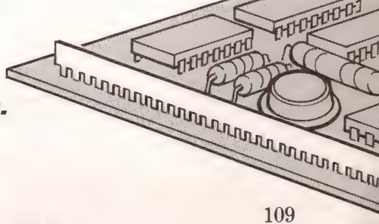

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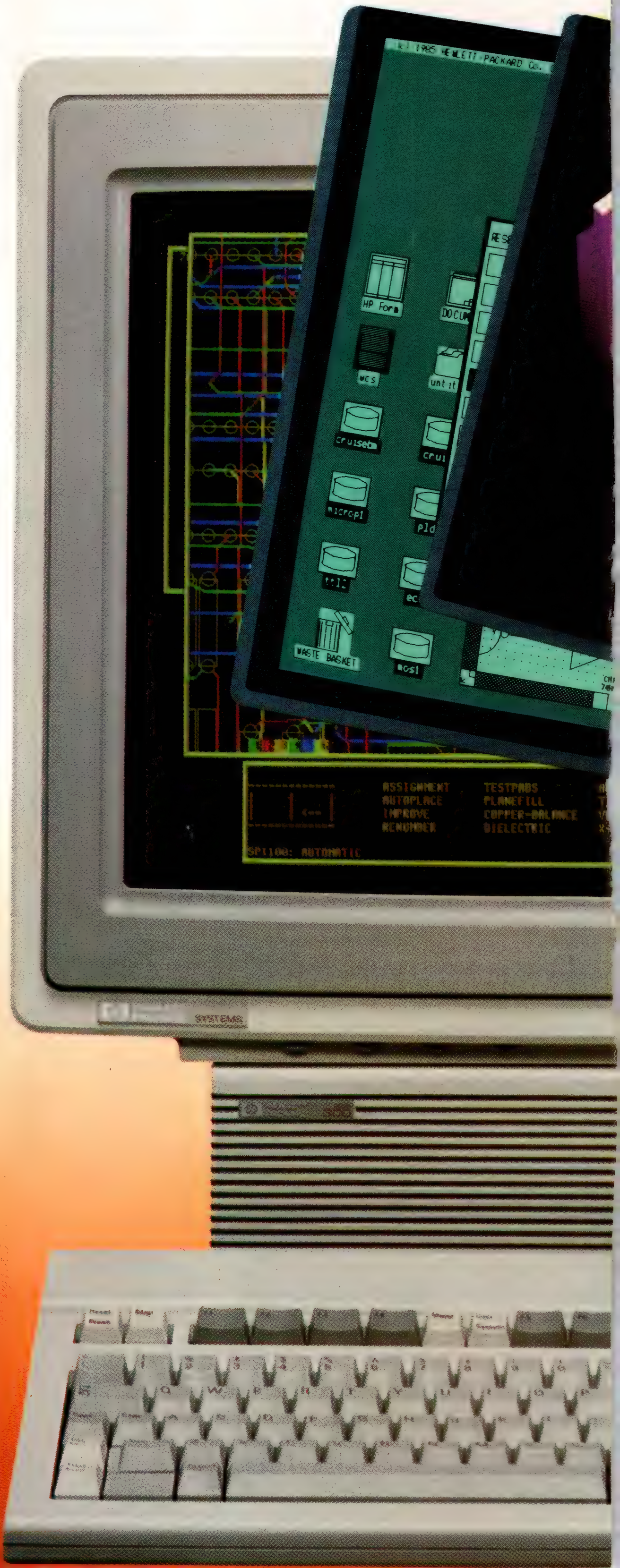

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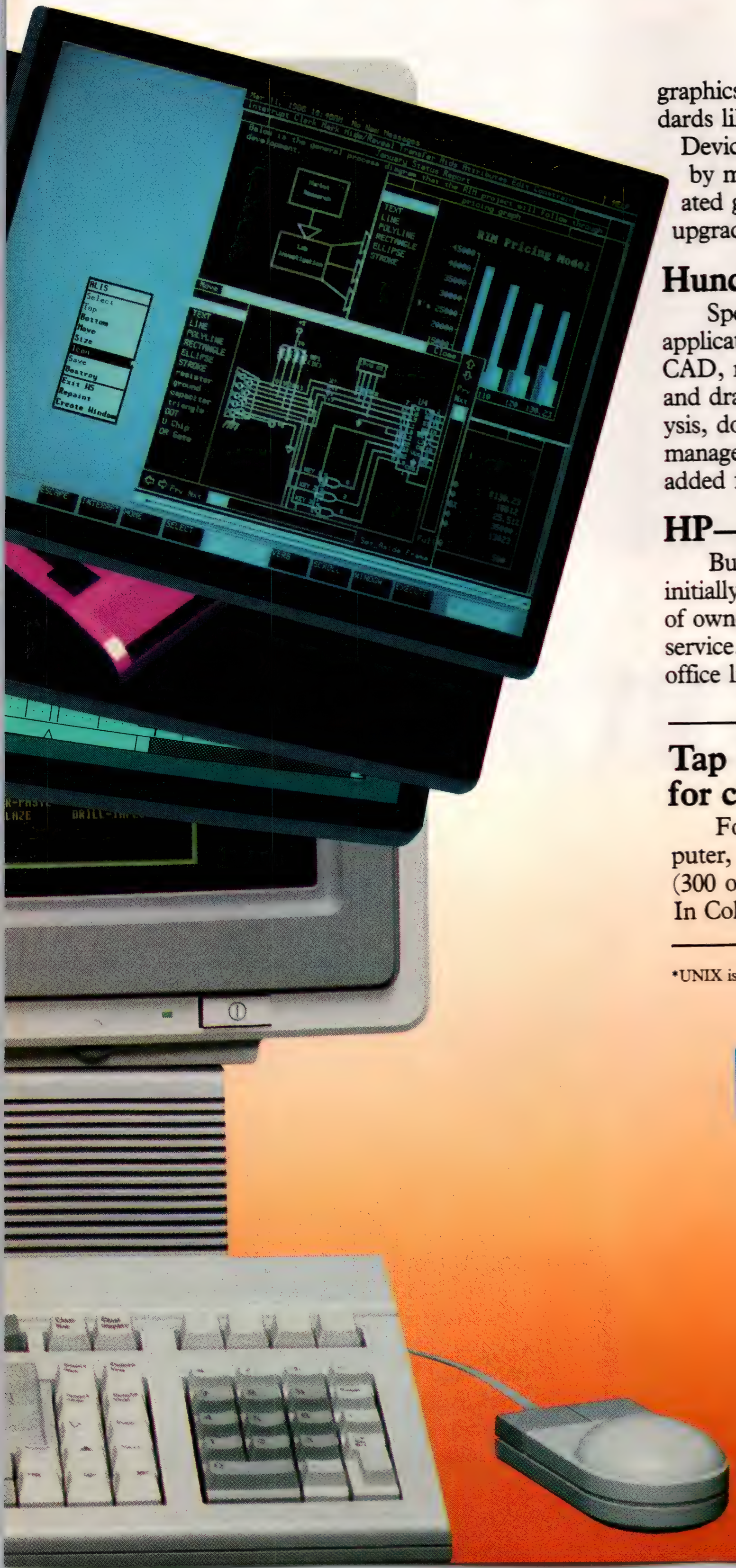

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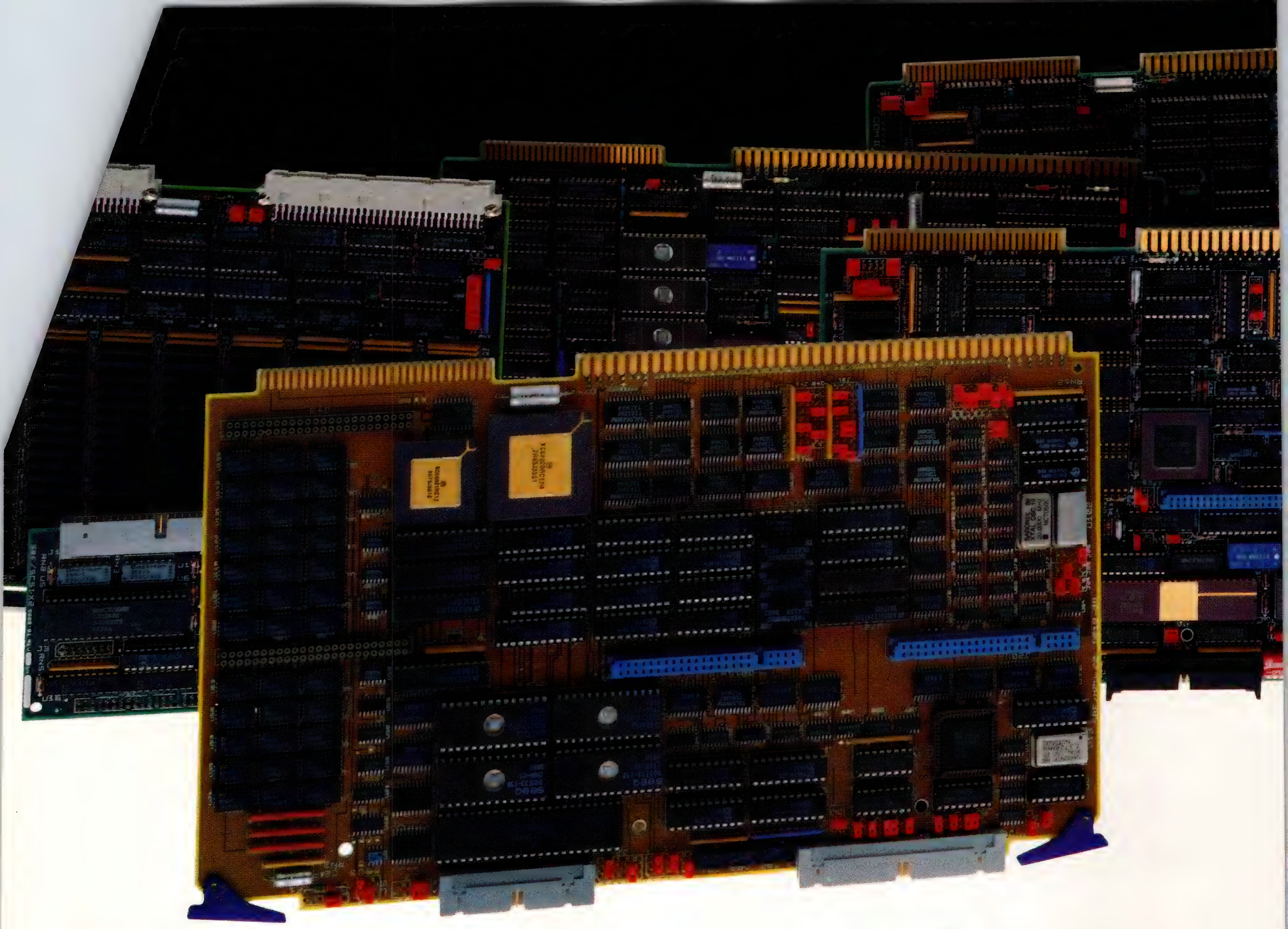

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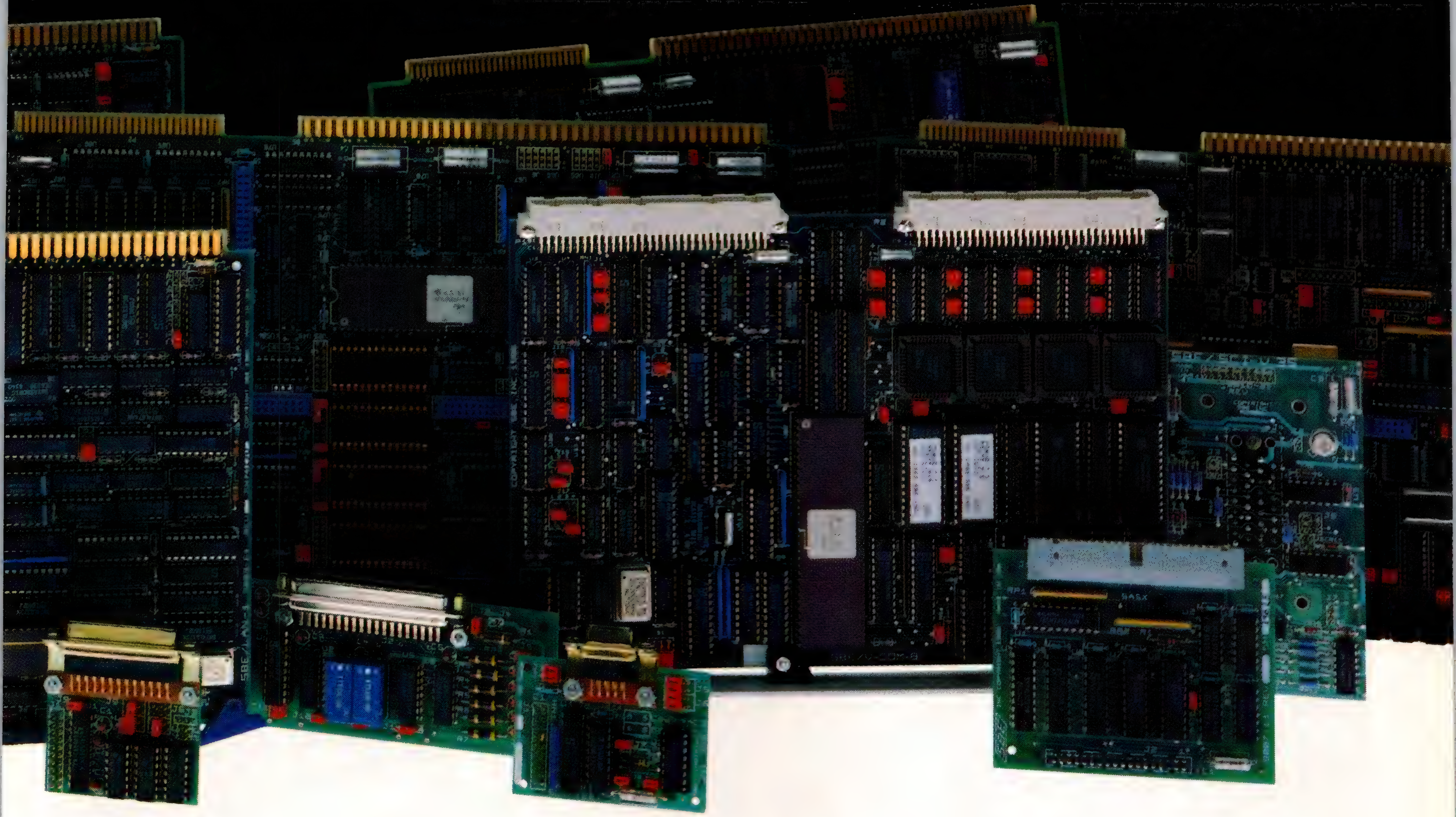

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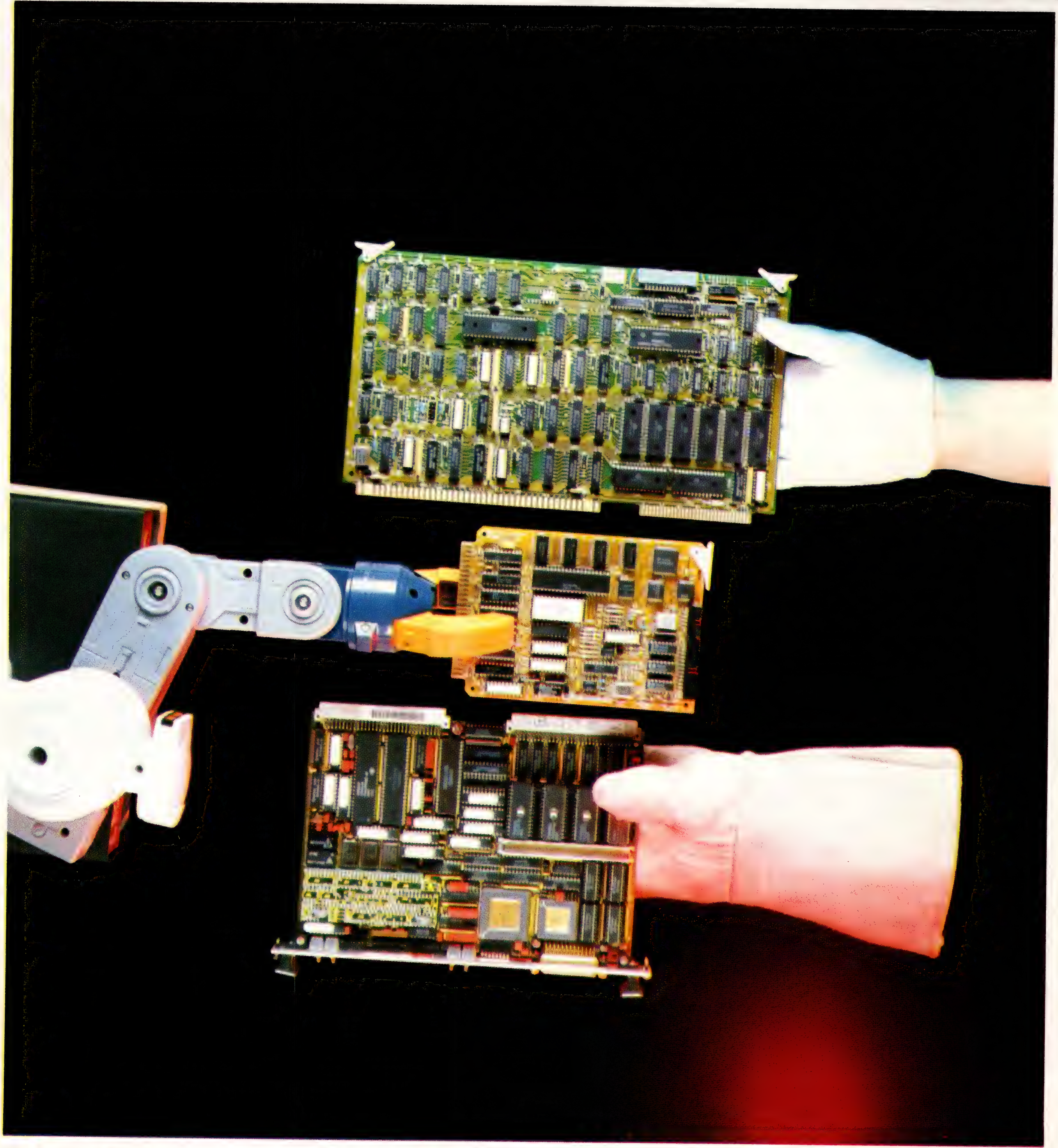
CIRCLE NO 77

Industrial buses



***The variety of computer boards and bus structures** is as extensive as the range of applications that they serve. When selecting a bus and deciding which functions to buy and which ones to design yourself, make sure you consider the needs of your application: A modern bus based on a state-of-the-art μP might be your best choice, but so might a reliable, established bus that's supported by many manufacturers. (Photo courtesy Pro-Log Corp)*

Don't let technology alone determine your choice of a computer bus. You can spend a lot of time arguing the technical merits of electrical and physical bus structures, but the keys to your selection don't necessarily depend on the CPU: Instead, board size, power requirements, and ease of interfacing may be the determining factors.

Jon Titus, *Editor*

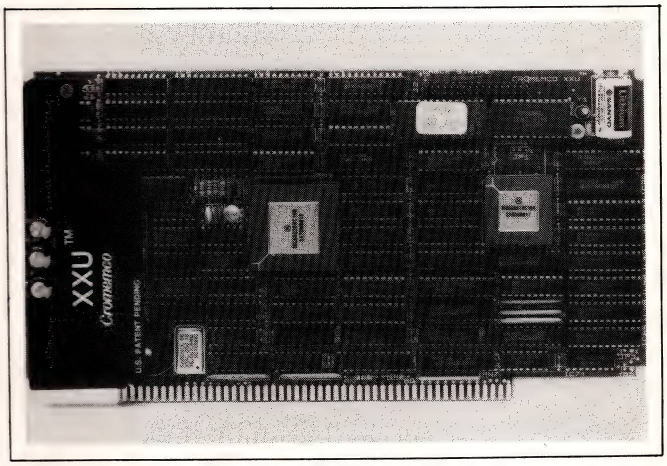
Too many people allow the attractions of state-of-the-art technology to determine their choice of a computer bus for an embedded controller, so they end up purchasing computer boards with more advanced or sophisticated functions than they need. For the most part, however, you don't need to concern yourself with whether or not a processor multiplexes information on a bus. Instead, you'll want to look for a computer bus that lets you get your project up and running quickly and at minimum cost. When choosing a bus, you'll also want to know about the availability of special-purpose I/O cards, controller boards, and CPUs that meet your needs. Because a project doesn't end when you ship the product, service and long-term support are also important considerations when you choose a bus.

If you're developing a computer that requires special-purpose interface circuits, you may have to design your own interface circuits. If such is the case, choose a bus that lets you design and test interface circuits easily. Although you have many buses to choose from, it's best to start looking at the ones that offer a broad range of functions and are already reasonably popular.

Many OEMs favor open buses that aren't tied too closely to individual manufacturers. Two such open buses are the PC Bus and the STD Bus. Although IBM developed the PC Bus, so many companies now offer compatible motherboards, buses, and add-in cards that IBM cannot control the way the bus specifications develop. Likewise, although Pro-Log developed the STD Bus, there are now so many suppliers of the bus, as well as a manufacturer's group, that the company could not independently make changes to the bus specifications. By providing momentum for a de facto standard, a group of companies can make it difficult for one company to control a standard for its own ends.

According to Harry Henry of The Marketing Information Center (Marlboro, MA), approved standards, low cost, alternative sources, and a future expansion path are among the industrial-bus user's highest concerns **(Fig 1)**. Bob Davis of Summit Computer Systems Inc (Los Gatos, CA) adds that some of the primary considerations in choosing a bus depend on four major factors:

- How long the end products will be in use
- How many of the products you'll make
- Who will service the products
- Who will do any necessary add-in work.



The S-100 Bus is alive, well, and expanding to 32 bits. *The XXU card from Cromemco includes a 32-bit MC68020 µP chip as well as memory and an optional MC68881 math coprocessor chip.*

The longer your product's useful life, the more your bus-board suppliers must be committed to long-term support. If a manufacturer is new or just starting in the bus market, carefully consider its past experience—if any—in supporting its products. If you're making only a few systems, you'll have to weigh engineering costs against the cost of buying ready-to-run cards. Although you may be able to engineer a proprietary system yourself, don't forget to consider the extra debugging and testing that all new designs require.

Davis suggests that if nontechnical people will be adding boards to a system in the field or replacing boards for service, the computer should be able to set itself up for operation without requiring the service people to change jumpers or switch settings. Also, because computers invariably require service, the board size, ease of repair, ease of replacement, and replacement cost are all important factors in your decision about which bus to use.

Lyn Hills, manager of marketing communications at Cromemco Inc, echoes the sentiments of many bus users when she says that bus markets are now driven by people's needs for solutions and not by their love of new technology. However, she adds, "Government bid situations are still difficult. To government people, the latest buzzword is attractive and they want it in the spec."

General-purpose microcomputer buses got their start in the Altair computer produced by MITS (Albuquer-

The S-100 Bus is still very much alive, although many people don't consider using it because it's almost 11 years old.

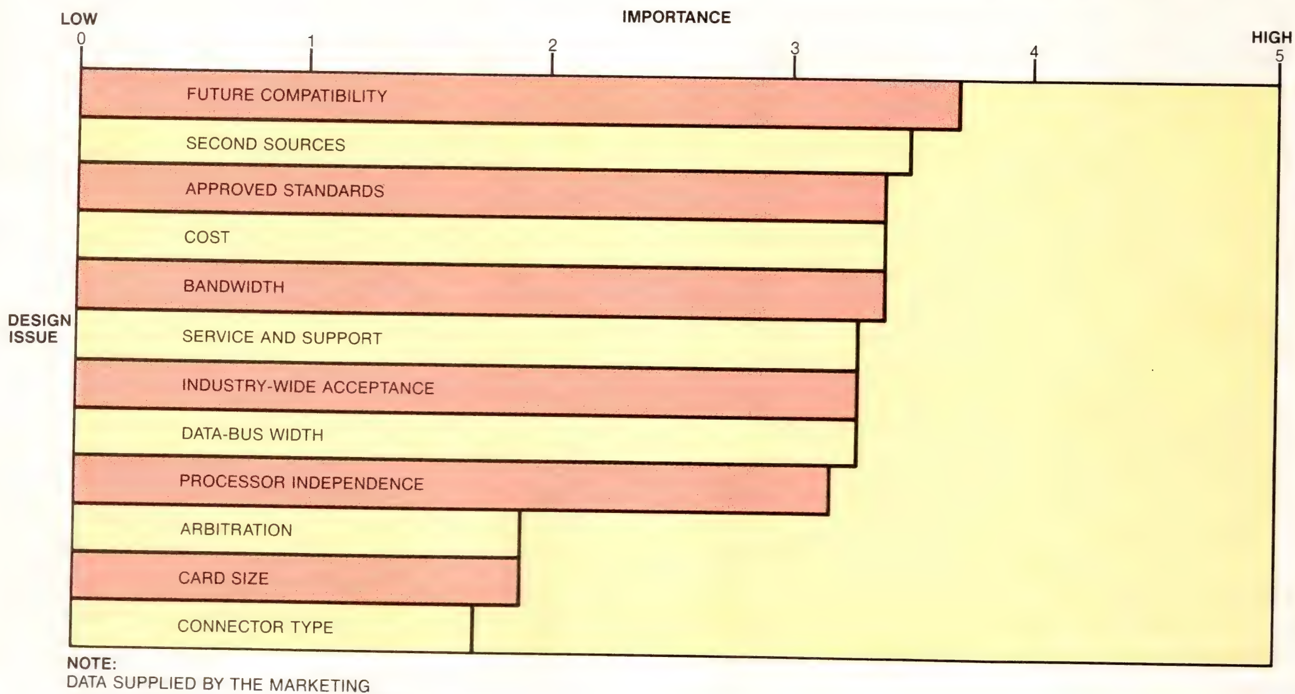
que, NM) in 1975. MITS has been out of business for some time, but its S-100 computer bus lives on. Although the S-100 Bus (IEEE-696) is now well defined **(Fig 2)**, no standard was set for the bus when it appeared in the first Altair computers. Inconsistent use of the bus's signals by manufacturers often led to incompatibilities among early S-100 boards. Many of the older S-100 boards, for example, had memory-address problems because of ambiguous I/O-port address assignments elsewhere in the computer. The standard S-100 bus now encompasses a bidirectional 16-bit data bus, a 24-bit address bus, and eight status lines. The bus also provides eight priority-interrupt lines **(Table 1)**.

Ernest Wassmann, vice president of marketing at Intercontinental Microsystems Corp, believes that the S-100 Bus has gone through a normal growth cycle but is now in decline. Lyn Hills of Cromemco takes a similar view. To her, the decision to use the S-100 Bus is more an emotional than a technical issue. People think the S-100 is obsolete because it is almost 11 years old, she says.

Cromemco won't abandon the S-100 Bus, even though it also plans to manufacture VME Bus products before the end of 1987. For example, the company now supplies a CPU board that incorporates a 32-bit MC68020 µP as well as an optional MC68881 math coprocessor chip and as much as 64k bytes of EPROM. About 90 other manufacturers still actively support the S-100 bus, and manufacturers recently formed the S-100 International Trade Association (SITA). The organization hopes to publish a newsletter and a manufacturers list. On the technical side, SITA is working on 32- and 64-bit extensions of the bus.

STD Bus cards are straightforward

Another bus with a long and active history is the STD Bus, which originated at Pro-Log Corp in late 1978. Mostek Corp (Carrollton, TX) joined with Pro-Log to sponsor the STD Bus concept. The current family of STD Bus vendors includes hundreds of manufacturers that offer broad lines of products as well as some vendors that sell only a few special cards. According to the basic STD Bus philosophy, customers buy only the functions they need. Thus, STD Bus manufacturers keep their cards straightforward. They don't cram disk



NOTE:
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Fig 1—Bus users' concerns aren't primarily technical. *Users point to future compatibility, second sources, and approved standards as their top three concerns when they choose a computer bus for an embedded controller.*

controllers, a CPU, memory, and I/O ports all onto one small card. Further, although the STD Bus is generally perceived as being an 8-bit bus, companies have been providing 16-bit computer systems on the bus for over a year.

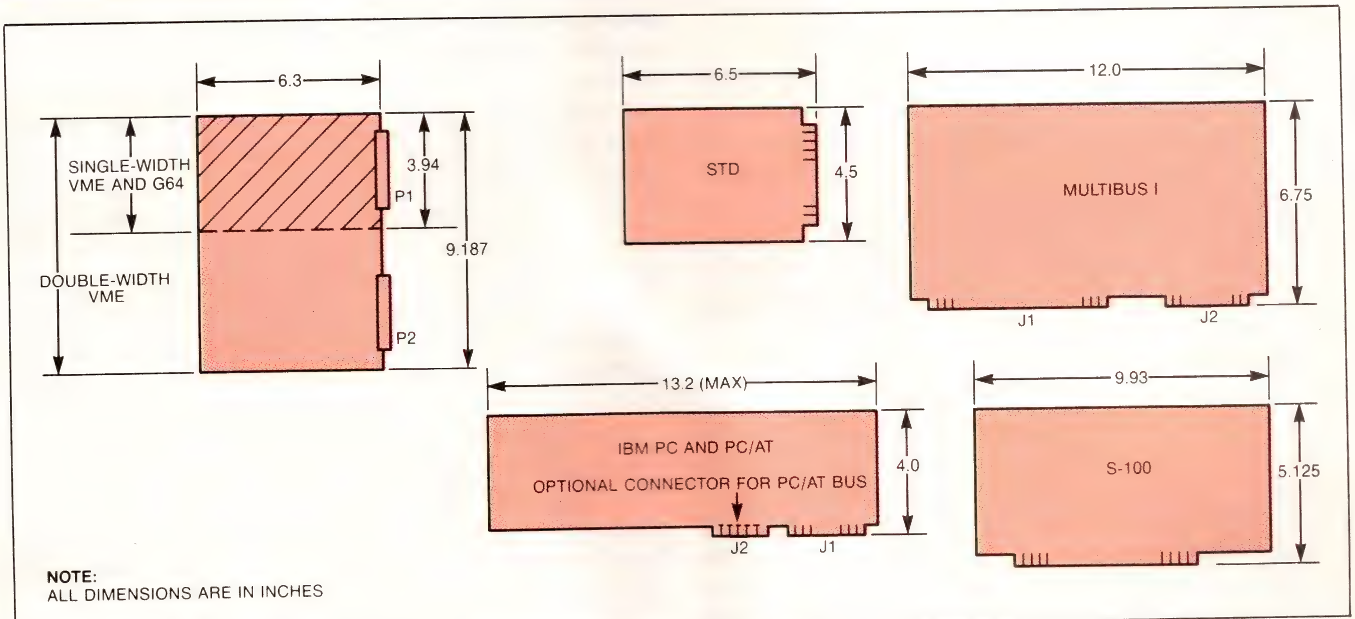
Because the STD Bus allows for a simple interface between computer and I/O cards and the bus, many users build their own cards when they can't find a function they need. Paul Virgo, marketing manager of Pro-Log, estimates that 45% of all STD Bus users build some of their own cards. "People will always need something special. The main point is that customers can do it because the bus is easy to understand, test, and debug."

The breadth of STD Bus products continues to expand from its start as a base for Z80 and 8080 μPs. Today, Pro-Log and Ziatech Corp actively promote the use of MS-DOS software in 8088-based STD Bus computers. Such systems enable users to run vast libraries of software on their small computer systems. Thus, the users can run sophisticated software while they control external devices with fairly simple STD Bus I/O cards.

TABLE 1—COMPARISON OF INDUSTRIAL-BUS CHARACTERISTICS

	BUS TYPE							
	S-100	STD	G64	VME	MULTIBUS I		IBM PC AND PC/AT	
CARD SIZE	9.93×5.125	6.5×4.5	6.3×3.94*	6.3×3.94*	12.0×6.75		13.2×4.0	
CONNECTOR	EDGE	EDGE	DIN	DIN	EDGE		EDGE	
					J1	J2	J1	J2
CONTACTS	100	56	96	96	80	60	62	36
SIGNALS:								
DATA	16	8	16	16	16	16	8	8
ADDRESS	24	16	16	23	20	24	20	7
CONTROL	45	22	23	43	26	13	25	19
POWER	9	10	9	14	20	6	8	2
RESERVED	3**	0	0	0	4	1	1	0

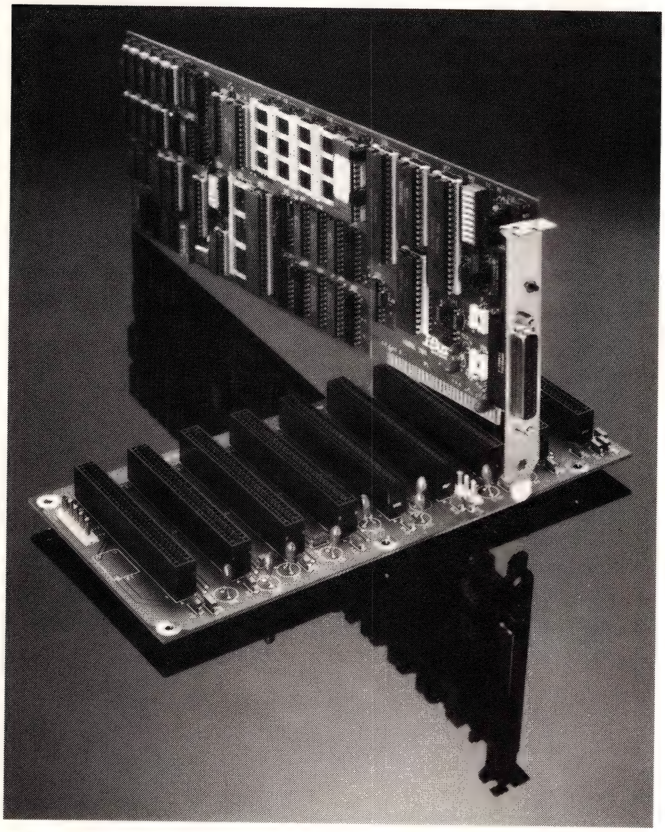
*EUROCARD FORMAT (ALL CARD SIZES ARE IN INCHES)
**S-100 BUS INCLUDES THREE UNDEFINED SIGNALS



NOTE:
ALL DIMENSIONS ARE IN INCHES

Fig 2—Industrial-bus cards *range in size from the small, single-width VME Bus and STD Bus sizes to the large Multibus I board. Bucking the trend, the IBM PC and PC/AT computers use long, narrow cards.*

The availability of MS-DOS software for the STD Bus opens numerous possibilities for sophisticated control applications.



***A 9-slot passive backplane for IBM PC boards** removes all the active circuitry from the motherboard. You select individual cards to meet your specific needs for the CPU and I/O functions. (Photo courtesy I-Bus Systems)*

Jim Eckford, vice president of sales and marketing at Ziatech Corp, views his customers as machine-control experts, not microprocessor experts. "These people can work with MS-DOS software. They're users, not computer nerds. They don't care about the bus, they're just comfortable with the PC-like atmosphere." However, even though its customers are familiar with the IBM PC, Eckford doesn't foresee the PC making big inroads into the STD Bus market.

Whenever engineers talk about buses, invariably someone reopens the old debate about the reliability of the card-edge connector (used on the STD Bus, the S-100 Bus, the PC Bus, and other buses) vs the reliability of the pin-and-socket (DIN) connector (used on the VME Bus, G64 Bus, and other buses). Eckford dismisses the controversy as a nonissue. In his 10 years of experience, he has yet to see a documented failure of a card-edge connector. Pro-Log's Virgo agrees, "With all that is packed on an STD Bus card now, components will probably fail before the connector does."

According to many users, few edge connectors have caused the problems ascribed to them in the folklore of computer engineering. Keep in mind that before the advent of the DIN connectors, many minicomputers worked flawlessly while using card-edge connectors, even under less-than-ideal conditions. If DIN connectors do offer an advantage over the card-edge connectors, however, the advantage is in density. A standard DIN bus connector provides 96 contacts; an edge connector that takes up the same space offers only 56.

STD Bus connectors aren't a problem, says Fred Cederblom, an engineer at Jet Propulsion Laboratories (JPL) (Pasadena, CA). However, on Multibus I computers, the connectors have been a problem simply because of the card size and the long connector length. Badge readers that use STD Bus computers have been operating at JPL for five years without a problem, although Cederblom notes that such computers might have problems in a high-vibration environment.

Consider long-term support

Cederblom likes the modular approach of the STD Bus because it lets him buy just what he needs and because the bus isn't proprietary. Multibus I boards, on the other hand, provided more functions than he needed. Further, he found errors in Multibus documentation from Intel, and he has found it impossible to get replacement PROMs and PALs for Intel boards. "Companies we deal with must be interested in long-term support—as long as 10 years for some JPL equipment," he says.

David Chase, an electrical engineering manager at Peak Systems (Fremont, CA) expresses wonder at the way some engineers select buses. He thinks that, overall, engineers stick with the approaches that others have used. Because few engineering schools expose students to buses or bus-selection criteria, Chase believes, a lot of engineers do seat-of-the-pants designs. "Many people will just say, 'Let's throw a 68000 at this problem.'" Chase adds that a person does not readily leave his base of hardware and software.

Chase, who has 12 years of engineering experience, intends to continue using the STD Bus. To him, software and software support are very important. Likewise, good vendor support, the large number of STD board suppliers, and the low cost of STD boards are important parts of his decision.

Peak Systems buys between 65 and 75% of the STD Bus cards that go into its equipment. Even though cards for the remaining functions may be available commercially, Peak builds them. For example, one of its custom 3-axis motor-control cards occupies one card slot. Using equivalent off-the-shelf cards would require extra slots in the computer. "The time spent on the interface is trivial," says Chase. "It's not a big problem anymore."

Although STD Bus manufacturers boast about alternate sources and the wide variety of available cards, Chase says that few drop-in equivalents exist. For example, two CPU cards may have the same μP, but each has its own options and enhancements. You can't just remove one card and replace it with an equivalent

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Organizations and publications offer help

Manufacturers of the major bus products often belong to groups that promote bus structures to both prospective customers and old ones. One such group, the VME Bus Industry Trade Association (VITA), offers a VME Bus Compatible Product Directory ($14.95 US; $19.95 elsewhere) that lists over 150 companies that manufacture VME Bus products. VITA has 55 company members and numerous individual members. The group also has an office in Europe.

For more information about the VME Bus, you can subscribe to *VMEbus Systems*, a bimonthly magazine (from the company of the same name) promoting the VME Bus. Subscriptions are free to qualified readers; others can subscribe for $16 in the US and Canada, $50 elsewhere.

A similar magazine for G64 enthusiasts, *G-64 Only*, is available from Gespac. A typical issue contains technical articles and information about new Gespac products. Subscriptions are free to qualified readers.

Multibus I and II manufacturers offer services through the Multibus Manufacturers' Group, which lists over 49 member companies. The group offers a booklet that covers Multibus products. You can get information about the STD Bus Manufacturer's Group (STD MG) from Pro-Log Corp. Both Pro-Log and Ziatech have been driving forces behind the STD Bus group for some time. The group is now working on the final version of its 16-bit bus specification.

Bob Varga of Faraday Electronics Inc will send you information about the new PC Extended Technology (PCET) standards committee, which is working on a 32-bit standard for the next generation of PC-type computers.

People interested in the S-100 Bus can contact the S-100 International Trade Association (SITA) care of Ernest Wassmann at Intercontinental Microsystems Corp. Wassman says that the group plans to start a newsletter and to publish a list of companies working on S-100 Bus products.

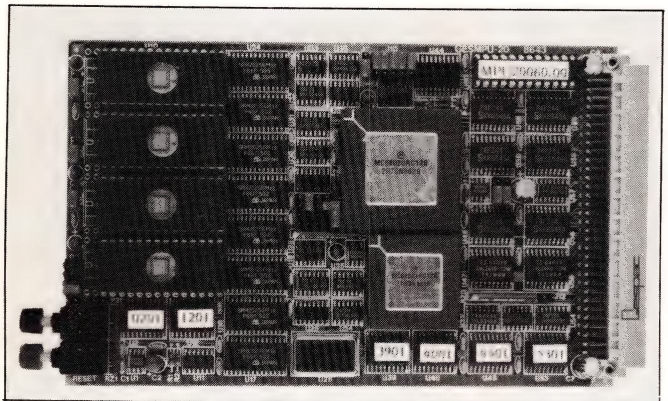
Books can also be a source of information about industrial buses. For a detailed and neutral look at the computer buses and the products available for them, consider the handbooks published by the Microcomputer Interface Group. Each handbook covers one microcomputer bus, and the group publishes new editions yearly. The volumes cost $39.95 each.

Further, Zebu Research Corp publishes a Who's Who for the board industry. The book lists manufacturers as well as the key contact people in each company ($250). The book doesn't cover many of the companies involved exclusively in the IBM PC bus market, however.

Seminars and trade shows also provide a great deal of information about buses and their capabilities. Many of the bus companies offer seminars about the buses they support and the products they sell. You can contact the companies individually to find out about their course schedules. For example, Micro/Sys offers a half-day seminar about using board-level computers in embedded systems. Seminars and technical papers are also presented at the Buscon shows (sponsored by MultiDynamics Inc), which take place on the West coast in the winter and on the East coast in the fall.

Finally, many manufacturers provide detailed data books, instruction manuals, and other technical information that tells you about their products and the specific buses they run on. An example is Pro-Log's extensive *Technical Manual and Data Book*. The book contains product specifications as well as application notes about how to use products, write software, and interface cards to I/O devices.

The G64 Bus extends the STD Bus concept to Eurocard boards that offer pin-and-socket connectors.



This G64-type card, *the GESMPU-20 from Gespac, provides an MC68020 µP and an MC68881 math coprocessor chip. The card supplies both RAM and PROM. Beneath the PROM sockets are additional surface-mount RAM chips.*

from another manufacturer. To protect yourself from losing a source of boards, Chase recommends that you have the manufacturer set up an escrow account. Such an account would contain a package of drawings, specifications, and other documents that you can obtain if the manufacturer drops a product or leaves the market.

The Syva Division of Syntex Corp (Palo Alto, CA) uses STD Bus boards in its blood analyzers. During product development, the company didn't have a lot of resources for electrical engineering. "We want to use off-the-shelf boards, mostly those relating to instruments," explains engineer Rob Burnside. The most important factors in choosing the STD Bus were modularity, cost, and serviceability, not raw CPU power. According to Burnside, the small, simple STD Bus boards help make it easy for service people to do on-site testing and repairing.

Despite his familiarity with the PC/AT, Burnside won't use an industrial version of the PC/AT for his company's instruments. For one thing, he says, the industry lacks the special I/O cards he would need for such a system. He also thinks that the rectangular STD Bus boards are more reliable mechanically than the longer PC bus cards are.

Alternatives to the STD Bus offer similar computer and I/O functions on small cards. One such alternative, the G64 Bus, was launched in Europe by Gespac Inc to answer the need for small computer boards that could be built into controllers. The G64 Bus uses standard single-width Eurocards and a 96-pin, pin-and-socket type-C DIN connector (DIN 41612). From the start, the G64 Bus set its sights on 16-bit µP applications. Although the G64 Bus has typically supported mainly the 6800 and 68000 µP families, it now supports the Z80, 8085, 8088, and other µPs.

Marc Marinello, marketing manager of Gespac Inc, sees the G64 Bus as the STD Bus of Europe and as a replacement for the STD Bus in North America. Because the company's G64 bus is in the same general market as the STD Bus and the single-width VME Bus, Gespac is in a tough market fight. Although it claims to have quite a few customers, Gespac is the only source of G64 Bus cards in the US. Europe boasts several additional suppliers, but in the US these companies are virtually unknown as G64 Bus vendors.

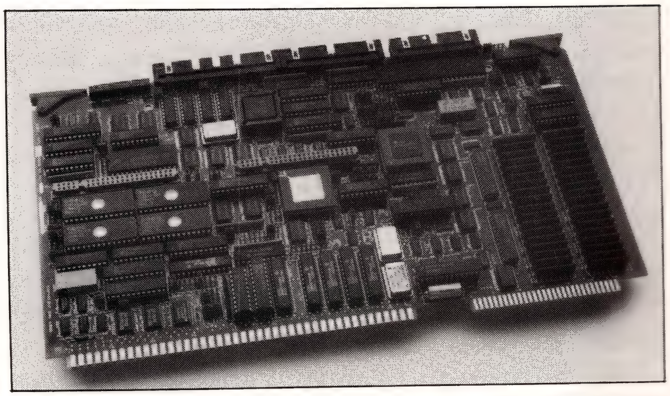
G64 Bus offers low-cost boards

The G64 Bus has its adherents, however. For example, Generic Technologies Inc (Horsham, PA) builds an optical-inspection system in which a 68000-based computer controls nine stepper motors. The low cost of the G64 Bus's 68000 CPU board was the overriding factor in the company's choice of the G64 Bus, says Al DiTullio. "The documentation seems to be a literal translation from a foreign language, but if you can put up with it and if you know the µP, it's no problem." However, he, an experienced engineer, warns that the G64 isn't a beginner's bus, although it could be if its documentation were better.

DeTullio isn't bothered about the lack of alternative G64 Bus product suppliers in the US. "There are no real second sources for most buses' boards. You can't take your PROMs and plug them into someone else's board and get them to run. Everyone has another feature or extra circuit that complicates things."

Because of his hardware and software experience with the 68000, DeTullio won't switch to another µP. Such a switch would force him to learn the new processor's cycle timing before he could accurately reestablish his system's real-time tasks. He would consider using the 68000 on the STD Bus, but he doesn't think the µP runs fast enough in that configuration for his needs. For real-time applications, he says, "Don't use an 8-bit CPU if you can justify the cost of a 16-bit computer."

Another G64 Bus user is Randy Robinson, who designed a vehicle-control system when he worked at Johnson Engineering Corp (Boulder, CO). Because the engineers at the company were familiar with the 68000, and because the project required a quick decision, his group chose the G64 Bus. The computer was going into a vehicle, so DIN-type connectors were necessary for added vibration resistance.



***Most Multibus I cards** include many functions. The MPU-12 from SBE Inc offers the main CPU as well as memory, I/O ports, special-purpose I/O controllers, and expansion connectors on one board. Note the two light-colored SBX connectors above the four EPROM chips and above the square chip in the center of the board.*

Robinson's company designed much of its own hardware. Of the 12 cards in the final computer system, eight were custom designs. The ease of interfacing circuits to the G64 Bus and the company's previous experience with the 68000 μP figured heavily in the decision to use the bus. Robinson thinks that the G64 Bus is an advancement of the basic STD Bus concept and that the G64 Bus offers a better connector. To improve the bus, he suggests, you should have a few uncommitted pins on it for special signals.

Although the G64 Bus didn't use all of the signals on the DIN connector, Gespac's new G96 Bus does. Actually, the G96 Bus isn't completely new. It simply adds to the signals on the G64 bus, extending the G64's address range to 24 bits. The 32 added signals include extra power, ground, and control lines. The data bus remains 16 bits wide.

You can also obtain 16-bit computers that operate on the VME Bus, which many engineers erroneously consider to be a 32-bit bus for large computer systems. Motorola joined with Mostek Corp (Carrollton, TX) and N V Philips/Signetics (Sunnyvale, CA) to develop the VME Bus standard (IEEE P1040), which the companies released jointly in December 1981. The VME Bus reflects its 16-bit heritage by offering both 16- and 32-bit data paths, as well as both 24- and 32-bit address paths. In fact, the VME Bus specification encompasses three buses: the global bus (VME), a local parallel bus (VMX), and a serial bus (VMS). Most VME Bus applications use the global bus. You might use the VMX Bus, say, to control I/O devices.

VME Bus cards come in two sizes: single-width VME cards with one DIN connector and dual-width boards that have either one or two DIN connectors. The smaller cards support 16-bit μPs; the larger cards can support both 16- and 32-bit μPs. The single-width cards are found more often in embedded computer systems than are their larger dual-width relatives. Most of the dual-width cards target higher-level applications.

Because the VME Bus specifications are now a proposed IEEE standard, Ray Alderman, vice president of sales at Matrix Corp, considers the single-width VME Bus boards to be part of a "bulletproof" specification—in other words, a spec that no one company will be able to control. In Alderman's opinion, the single-width boards are ideal for building controllers that don't require a console, keyboard, or display. And although the dual-width boards aren't aimed at the controller market, he acknowledges that some of these boards find use in that market.

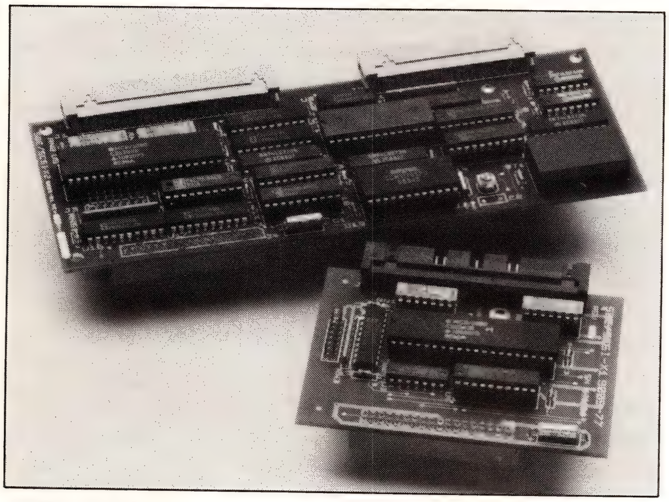
Alderman thinks users should avoid racing headlong to upgrade 16-bit computers that may not need upgrading. He adds, "All buses have a place, but be careful which pieces of technology you use—and at what price. If you're bottling beer, use a programmable controller. Some tasks just don't require a computer."

Dan Farkas of Owens Illinois Inc (Toledo, OH) decided to use a 68000-based computer in his department because a sister department had experience using the 68000 μP. The single-width VME Bus card he buys from Mizar Inc supports the VMX I/O bus, which helps unload routine I/O tasks from the CPU. However, Farkas and other users are becoming impatient as they wait for manufacturers to offer more functions on VMX Bus-compatible cards. Possibly because the specifications for the VMX Bus are not completely defined, companies hesitate to invest in new VMX Bus designs.

Also, cautions Farkas, "Not all of the commercial backplanes are equal. The quality of the signals varies. We had good results with the Motorola, Schroff, and Dawn VME backplanes. Some of the others caused lockup and bus errors." To test the backplanes, Farkas ran seven processors, each of which tested the memory on one of the other CPU boards. He suggests keeping an eye on the type of termination on the bus—passive or active. He found that active terminations gave the best results in his application.

In your search for a useful bus, don't overlook Multibus I. Although the bus has been in use since 1976, the bus's originator, Intel Corp, and many other companies actively support the bus with new products. The original 8080-based Multibus (now called Multibus I) computer board provided two card-edge connectors, an

The IBM PC Bus is available on passive mother boards that let you select just the functions you need.



Additional I/O functions on small cards *connect to the SBX connectors on Multibus I cards. The small cards, which are SCSI controllers from SBE Inc, add circuits without taking an extra bus slot.*

86-pin connector for the main bus signals, and an auxiliary 60-pin connector.

The main bus now encompasses 20 address signals and a 16-bit data bus. The auxiliary connector has evolved into the local LBX Bus, which supports communications between memory and I/O devices that usually operate with one CPU board. The LBX Bus supports 24 address lines and 16 data lines. The Multibus I boards also include an onboard SBX I/O connector that lets you connect small daughter boards directly to the Multibus I CPU card. The 44-signal SBX Bus contains three address lines and 16 data lines.

Multibus board manufacturers such as Central Data Corp offer a variety of SBX modules that extend the utility of Multibus I computer systems without requiring you to add extra cards to your computer. Central Data also supplies an SBX motherboard that lets you mix and match as many as six SBX modules on one Multibus I card.

In early 1980, Intel began development of Multibus I's successor, Multibus II. The new bus specification was released in November 1983, but so far there has been little activity to suggest that manufacturers are aiming the bus at industrial-control applications. In general, the bus suits applications that require a great deal of 32-bit processing power—a graphics processor or a multiprocessor computer system, for example. Detailed information about Multibus I and II is available from the Multibus Manufacturer's Group.

Although the Multibus I specification now extends to only a 16-bit data bus, Tom Powell, an engineer at Synergy Microsystems Inc (Encenitas, CA), believes it will eventually extend to 32-bit CPUs. He says that by placing an MC68020 μP chip and 4M bytes of local memory on one Multibus I card, you can have programs in the local memory that operate with the 32-bit CPU at full speed. The computer treats the Multibus I signals as a path for communication with other cards for I/O and control purposes. Thus, Multibus I manufacturers can offer you more processing power without forcing you to relinquish your previous investments in I/O and control boards.

Abe Abramovich at Control Automation Inc (Princeton, NJ) wants to keep the investment he has in Multibus I boards. Instead of switching buses, he expects to take advantage of the more-advanced technologies that continue to appear on Multibus I cards. Abramovich's company bet its circuit-board inspection system on Multibus I computers, reasoning that the standard wouldn't run out of steam with Intel behind it.

Multibus I and II offer design contrasts

As for interfacing, Abramovich says, "The Multibus I hardware is well-defined and handbooks are available, so it's not difficult to grind through designs. In contrast, Multibus II isn't easy to design with. As for Multibus I, the mechanics were the worst part; mechanically, it's not robust."

Although the Multibus I finds use in new applications, Mike Heins, CPU and systems product manager at Central Data, admits that if you don't have experience with a bus, you'll probably choose the VME Bus instead of the Multibus I. However, he quickly adds that unless you want a 68000-family processor, the VME Bus may not be your best bet, because so few other processor families are available on that bus. Heins also says, "Keep in mind that peripherals and I/O boards are still 8- and 16-bit devices. The new 32-bit boards are sexy, but support may not be available."

More than enough support is readily at hand for the IBM PC's expansion bus. The availability of complete technical specifications and the wealth of software and software-development tools make the PC suitable for many industrial tasks. The original IBM PC provides a large mother board that contains the main computer, memory, and five expansion connectors. However, after you add the cards that are necessary for the computer to operate, few expansion connectors, or slots, exist for control and I/O cards. Luckily, newer computers such as the IBM PC/XT, PC/AT, and compatibles offer additional slots for add-in boards.

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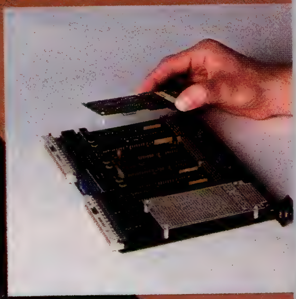

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By offering a small passive bus instead of a large motherboard in their PC-compatible computers, several manufacturers follow the approach taken by Zenith (Benton Harbor, MI) in its Model Z-150 PC-compatible computer. The computer's small passive-bus board contains no active electronics and is more rigid than a large motherboard. Plug-in boards provide the CPU, memory, disk controllers, and other necessary functions. Such computers can be expanded quickly and thus are

For more information . . .

For more information about the industrial-bus products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or contact the following manufacturers and organizations directly. Keep in mind that there are many more manufacturers of industrial-bus products than we can list in a single article.

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Cromemco Inc
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(415) 964-7400
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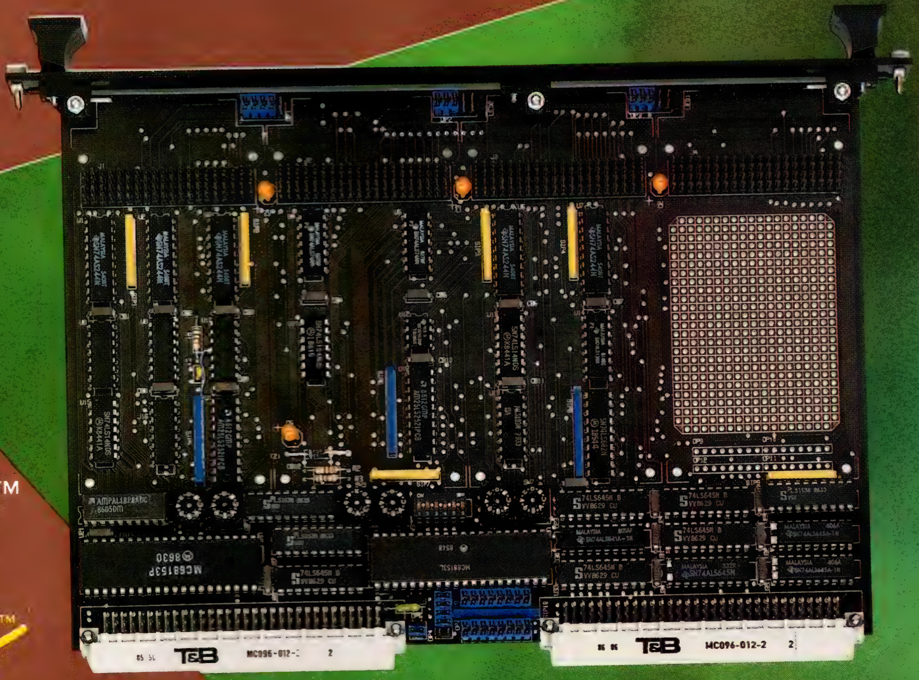

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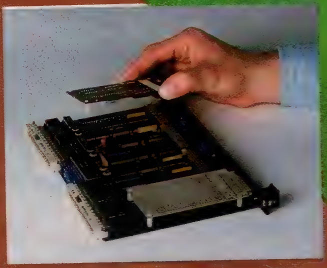

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makes a 64K bipolar PROM that, at 35 nsec, is 30% faster than any other on the market?

(See page 182)

not limited to the five or eight expansion connectors available in an active-motherboard-type computer. Placing the functions on the individual plug-in boards lets you mix and match the exact computational, memory, and I/O functions you need.

John Choisser, general manager of I-Bus Systems, claims that his organization originated the industrial PC and PC/AT bus concept. According to Choisser, most people using the PC bus in industrial environments haven't used a bus-type computer before. He believes that such users feel comfortable with the PC and are used to adding boards to their own computers. Therefore, he says, a person is less likely to be intimidated by using his PC with the PC bus than by using a VME Bus computer for the first time.

Although it's easy even for beginners to use, the PC bus isn't limited to operating in clean, benign environments. For example, Jim Newman of the Woods Hole Oceanographic Institution (Woods Hole, MA) designed a PC-based computer system to control the submersible vehicle that explored the wreck of the Titanic. The computer had to be simple, dependable, and easy to implement, and it had to be able to operate inside a submarine. Because he had experience with the IBM PC/AT computer, Newman thought the PC/AT would be a good choice. His application didn't cause a severe speed bottleneck on the PC/AT bus, and he could choose from many add-on cards. Even though the PC would have to operate in a hostile environment, the choice of a connector type wasn't a major decision. Newman was a little superstitious about the reliability of card-edge connectors, but the system had no problems.

You can find PCs on the ocean's surface, too. Several ships now rely on a PC-based computer that monitors their discharge of oil into the sea. If the oil concentration goes over a preset limit, the computer shuts a valve and stops the discharge. Mel Bembenek, president of Alpha Systems Inc (Broken Arrow, OK), used an industrial version of a PC/XT computer to perform the monitoring and control operations. He recommends designing with available boards and adding as little of your own circuitry as possible. His only contributions to the computer's hardware were signal-conditioning circuits. Says Bembenek, "You really don't know about the project until you're in the middle of it. There are lots of hidden things that aren't obvious at the start, even if you do your research." **EDN**

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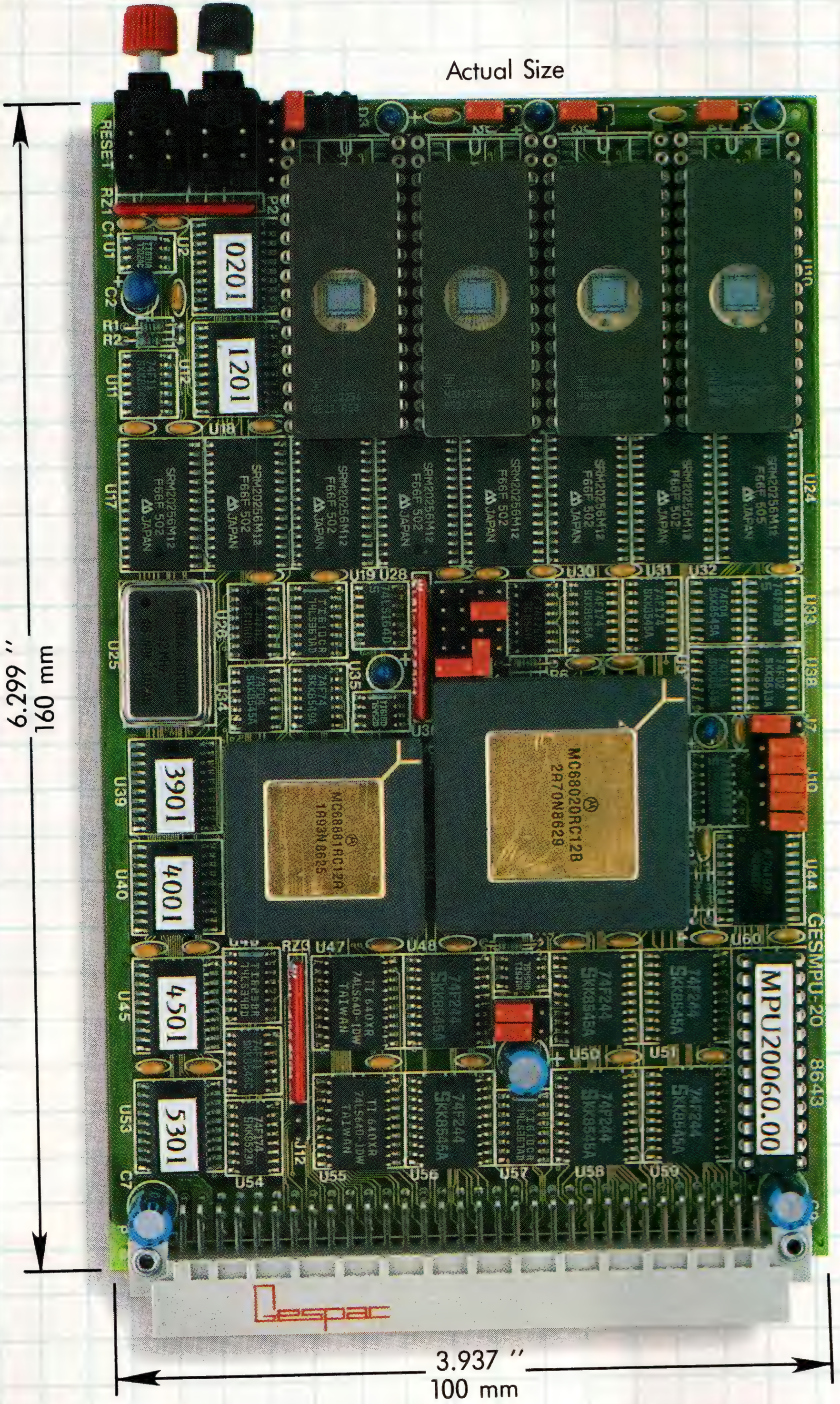

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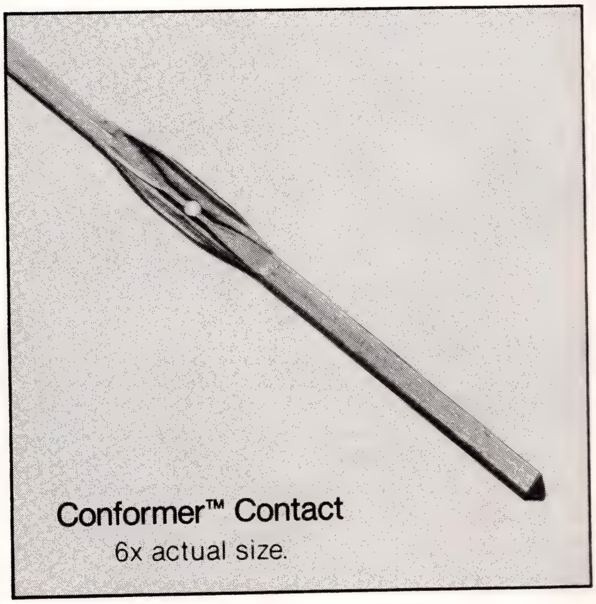
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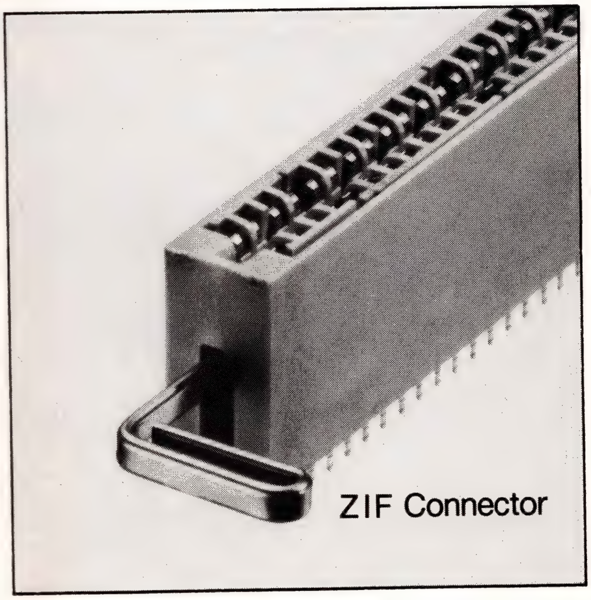
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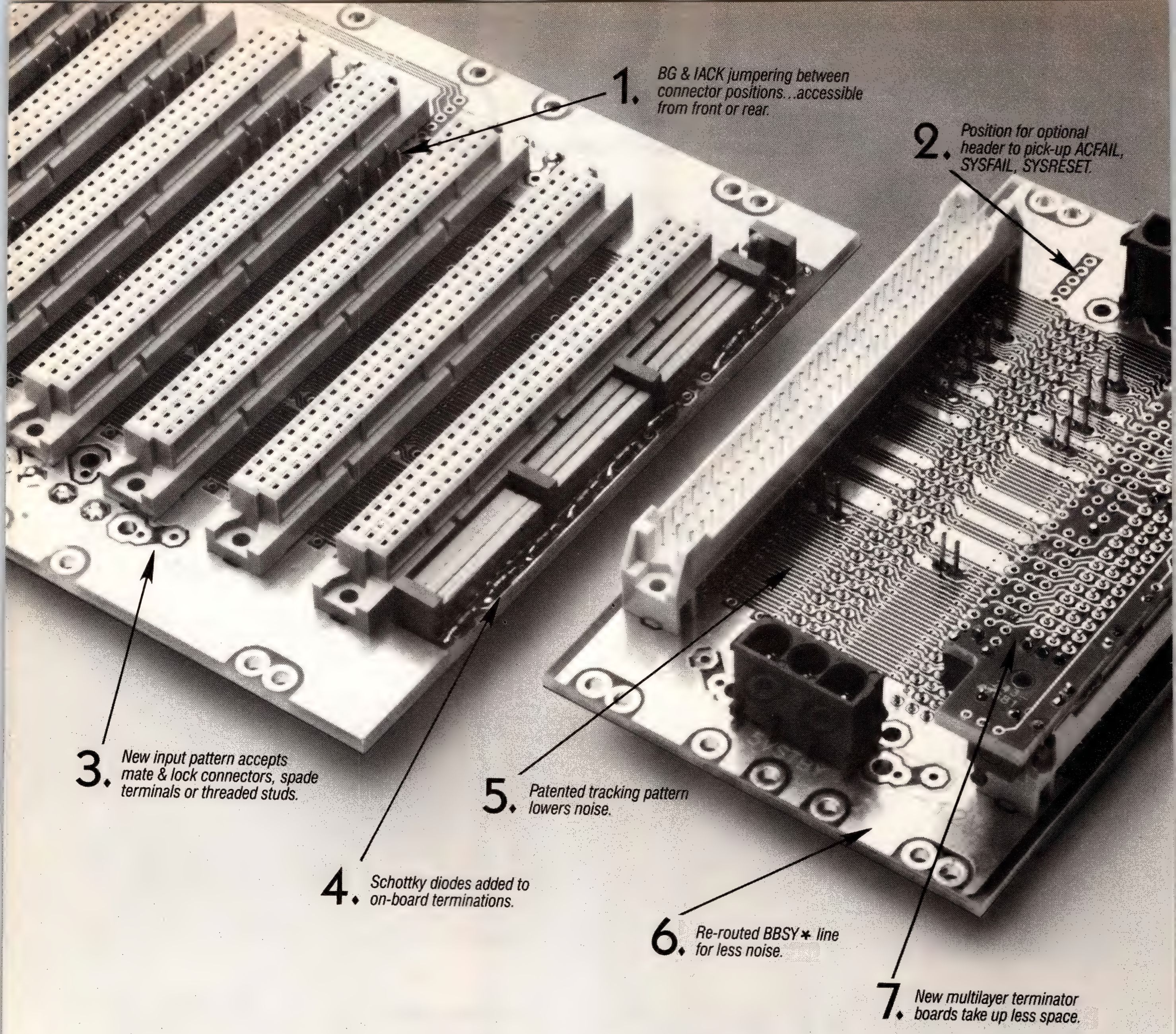

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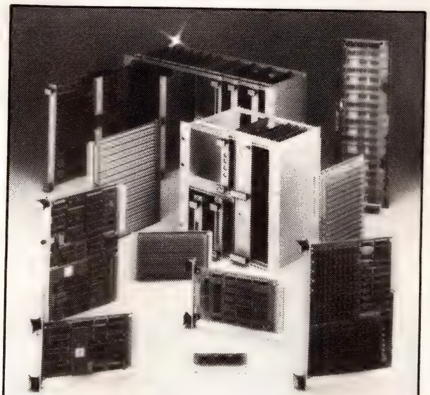

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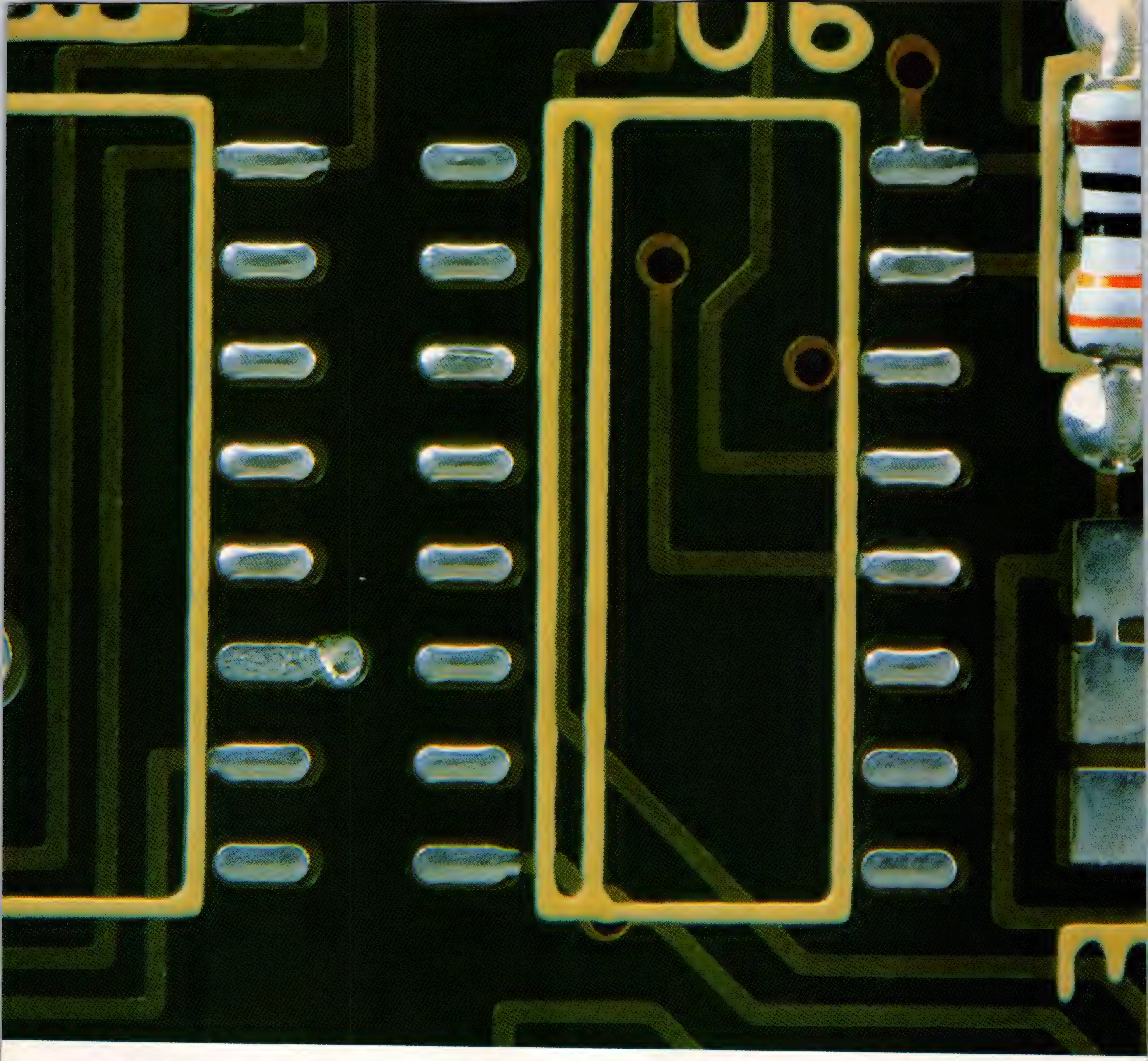

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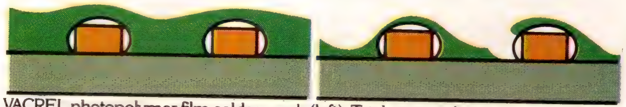

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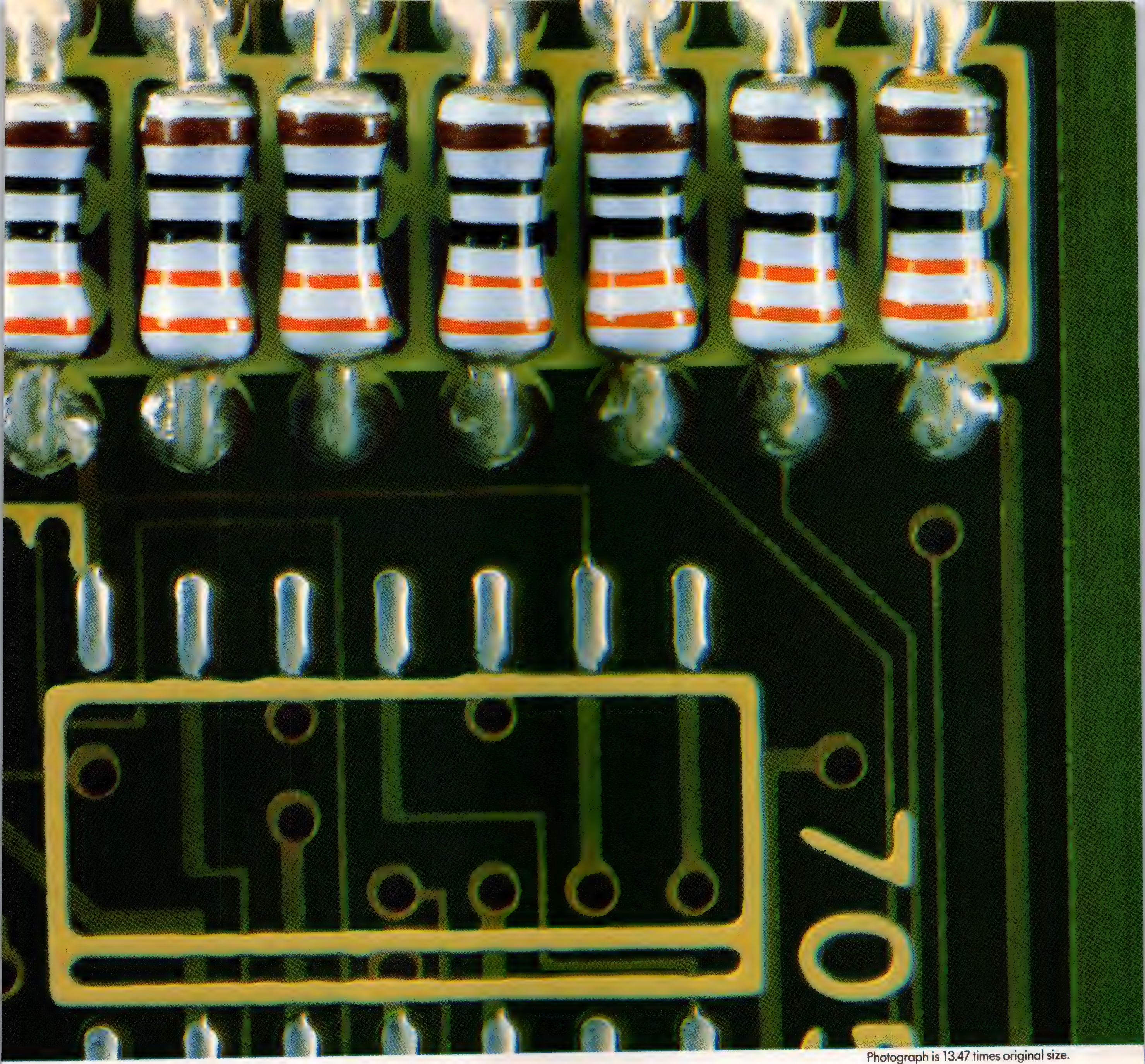

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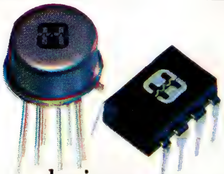

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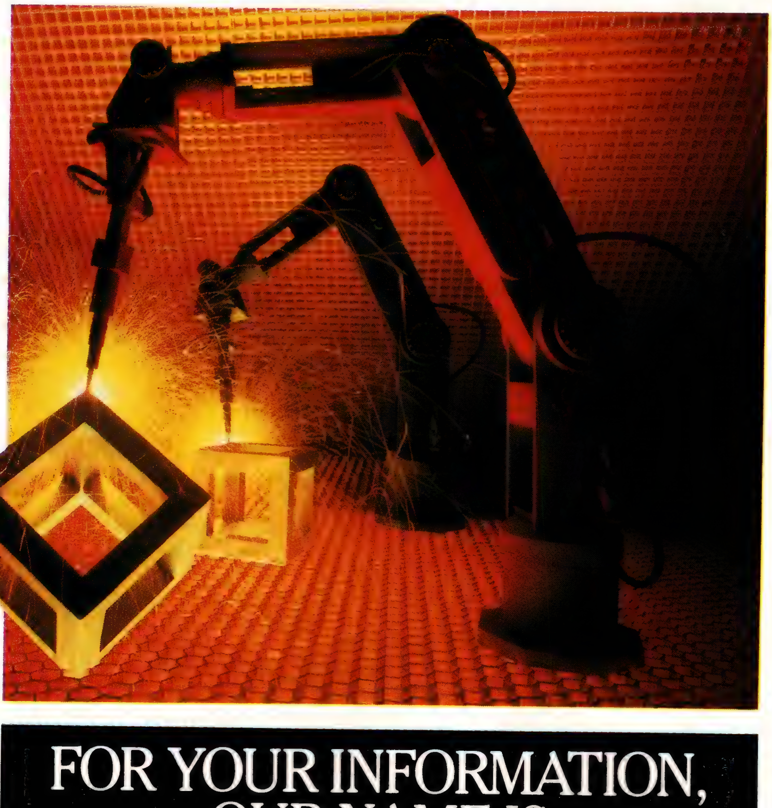

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Thermal-tracking IC converts rms to dc

An easy-to-use IC allows you to configure circuits that accurately convert the rms value of a waveform to a dc voltage. Operating on thermal principles, the device provides much greater speed than you can obtain by using logarithmic computing techniques. Further, the IC is relatively insensitive to a waveform's crest factor.

Jim Williams, *Linear Technology Corp*

To effect accurate rms/dc conversion for high-bandwidth and large-crest-factor waveforms, thermal conversion is the method of choice. Thermal conversion provides substantially improved bandwidth (100 MHz vs 250 kHz) and crest-factor (50:1 vs 10:1) capability, as compared with circuits (for example, some monolithic ICs) that use logarithmic computations. Instead of using large and expensive discrete-component thermal converters, you can now bring the advantages of thermal conversion to your system by using an IC, Model LT1088, that comes in a 14-pin DIP.

A waveform's rms power is defined as its heating power in a load. Many specialized instruments use thermally based assemblies that compute the rms value of their inputs. In fact, such applications as wideband rms voltmeters, RF-leveling loops, wideband AGC (automatic gain control), high-crest-factor measurements, SCR monitoring, and noise measurements require the advantages of thermal conversion. Thermal rms/dc converters are direct-acting, thermoelectronic analog computers. The thermal technique is explicit; its simple operating principle offers wideband performance that's unattainable from implicit, indirect methods based on logarithmic computing.

You can use the LT1088 in a wide variety of circuits, but before considering the practical applications information, it's worthwhile to review thermal rms/dc conversion in general, and the LT1088's conversion principles, construction, and operating characteristics in particular.

Fig 1a gives a conceptual diagram for a thermal rms/dc converter. The input waveform warms the heater; the result is increased output from the temperature sensor. The amount of heating is a function of the rms value of the input waveform, and the temperature sensor's dc output represents the amount of heating. Although this method is simple, the temperature sensor cannot distinguish between temperature changes induced by signals and those induced by ambient temperature.

You could address this ambiguity by summing in the ambient-temperature information, but a more significant problem remains. Even if the electrical portions of the design are perfectly linear, the overall response is not. The power the heater produces is nonlinearly related to the input voltage according to $P=V^2/R$, so the temperature rise is also nonlinearly proportioned. You need additional nonlinear signal conditioning to obtain an output that corresponds linearly to the input voltage.

Fig 1b shows a classic scheme that corrects both the deficiencies of the configuration in **Fig 1a.** Here, the dc amplifier forces a second, identical heater-sensor pair to assume the same thermal conditions that exist in the input-driven pair. This differential-sensing, feedback-enforced loop makes any ambient-temperature shift a

> *Thermal conversion beats out logarithmic-computation methods for the rms/dc conversion of high-bandwidth and large-crest-factor waveforms.*

common-mode term and eliminates the effect of the shift. Also, although the voltage-thermal relationship is nonlinear, the input/output voltage relationship is linear and the gain is unity.

The ability of **Fig 1b**'s circuit to reject ambient-temperature shifts depends on the heater-sensor pairs' being isothermal (at equal temperature), yet thermally isolated from each other at the same time. You can achieve this thermal isolation by thermally insulating the pairs with a technique that yields a thermal time constant well below that of the ambient shifts. If the

TABLE 1—THERMAL RESISTANCE VS DIE-ATTACH METHOD

DIE-ATTACH METHOD	THERMAL RESISTANCE (°C/W)
AIR SUSPENSION	460
AIR-IMPREGNATED POLYMER	300
EPOXY/2-MIL POLYMER BARRIER	250
10-MIL GLASS	115
EPOXY/1-MIL POLYMER BARRIER	107
EUTECTIC	54

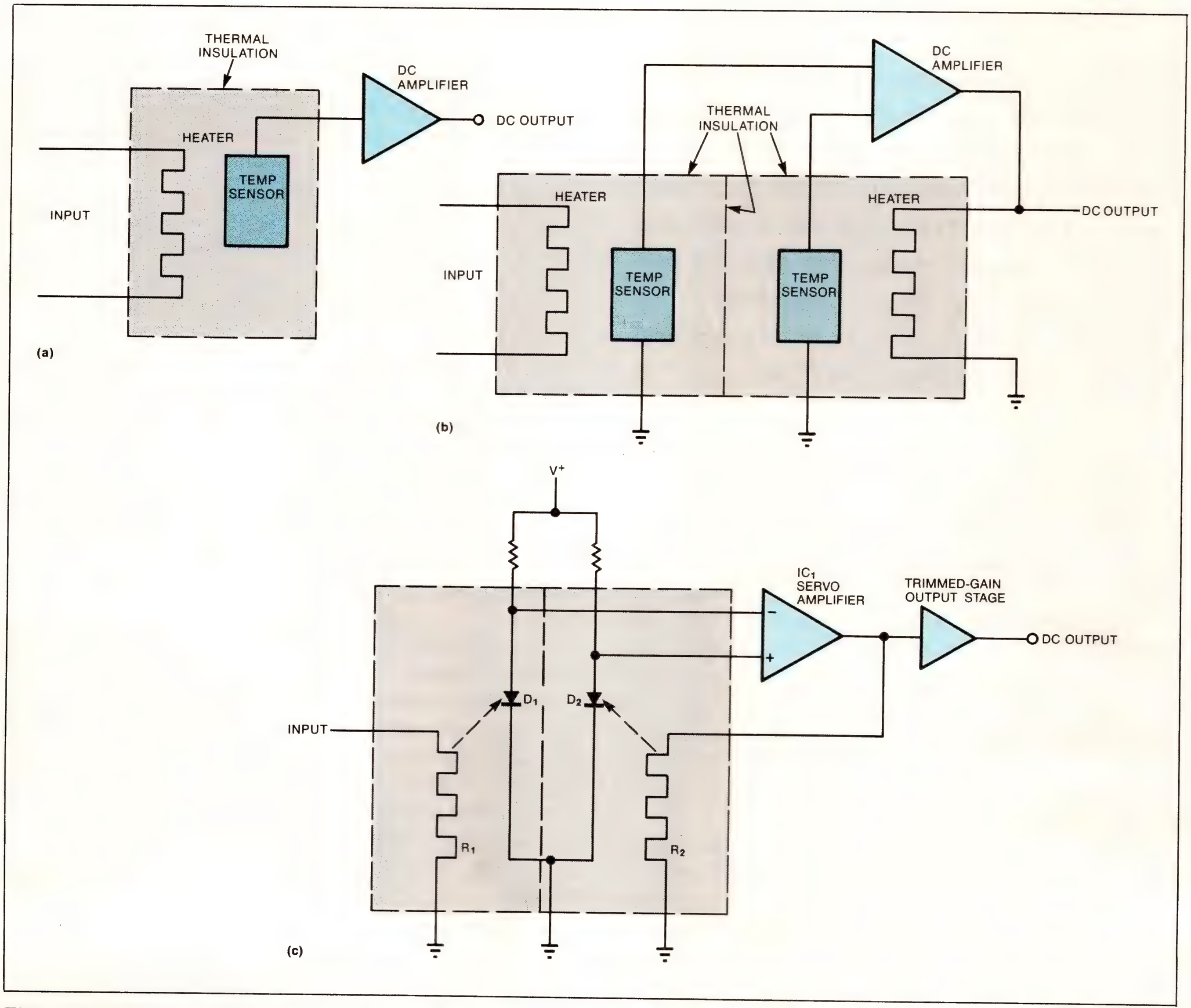


Fig 1—An rms/dc converter is simple in concept, *as these block diagrams illustrate. The simplest* ***(a)*** *suffers from nonlinearity of the input/output transfer function. The circuit in* ***b*** *corrects this nonlinearity. The configuration in* ***c*** *is a monolithic implementation of* ***b's*** *circuit; it uses resistors as heaters and diodes as sensing elements.*

TABLE 2—TYPICAL SPECS FOR FIG 5'S CIRCUIT

ACCURACY	
50Ω INPUT DC TO 50 MHz	1% FS
DC TO 100 MHz	2% FS
250Ω INPUT DC TO 10 MHz	1% FS
TEMPERATURE EFFECT ON ACCURACY	100 PPM/°C
DYNAMIC RANGE	20:1
CREST FACTOR	
50Ω INPUT	50:1
250Ω INPUT	40:1
3-dB BANDWIDTH	300 MHz
SETTLING TIME (FULL-SCALE, TO 1%)	500 mSEC
INPUT RANGE	
50Ω INPUT	4.25V
250Ω INPUT	9.5V

TABLE 3—SUMMARY OF BUFFER CHARACTERISTICS

BUFFER TYPE	GAIN	SLEW RATE	1%-ERROR BANDWIDTH 250Ω LOAD (±10V)	1%-ERROR BANDWIDTH 50Ω LOAD (±5V)
DISCRETE (FIG 17)	10	3000V/μSEC	25 MHz	32 MHz
LT1010-BASED (FIG 16)	10	100V/μSEC	0.75 MHz	2 MHz
DISCRETE (FIG 15)	1	2000V/μSEC	15 MHz	25 MHz
LT1010-BASED	1	100V/μSEC	0.75 MHz	2 MHz

thermal time constants to the heater-sensor pairs are matched, ambient-temperature terms will affect the pairs equally in phase and amplitude.

The dc amplifier in **Fig 1b** rejects the common-mode signal caused by the ambient shift. Note again that, although the pairs are isothermal, they are thermally insulated from each other. Any thermal interaction between the pairs would reduce the system's thermally based gain terms. This reduction would cause unfavorable signal-to-noise performance and thus limit dynamic operating range.

In **Fig 1b**'s circuit, the output is linear because the matched thermal pairs' nonlinear voltage-temperature relationships cancel each other. The advantages of the described approach make its use popular in thermally based rms/dc measurements. However, the assembly typically comprises matched heater resistors, sensors, and thermal insulation. These assemblies are relatively large and expensive to produce. In theory, you could use monolithic-IC techniques to replace such assemblies, but—as you'll see later—the thermal-insulation requirements present problems.

A simplified monolithic-IC-based circuit that accomplishes the described conversion function appears in **Fig 1c.** The operating principle of this circuit is quite similar to the generalized approach of **Fig 1b**'s circuit. Here, the input drives R_1, producing heating that lowers the value of D_1's forward voltage. IC_1 responds by driving R_2 to heat D_2, thereby closing a loop around the amplifier. Because the diodes and resistors are matched, IC_1's dc output equals the rms value of the input waveform, regardless of the input's frequency or wave shape.

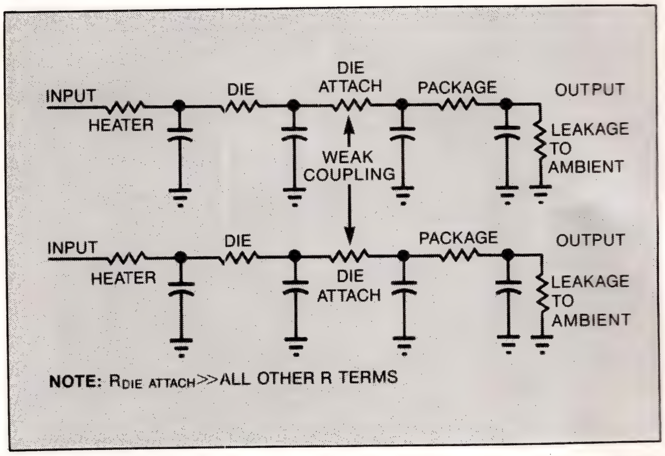


Fig 2—This circuit, an electrical analog of the thermal terms in the LT1088 rms/dc converter, shows the various thermal-resistance values in the IC. Die-to-die thermal-resistance and thermal-time-constant matching is important, as is a high value for the die-attach thermal resistance.

The thermal terms described earlier limit the circuit's practical performance capabilities. In particular, thermal cross coupling between the R_1-D_1 and R_2-D_2 pairs degenerates the gain and thus degrades the available signal. Also, differences in the dissipation constants and thermal capacities of the R-D pairs result in overall gain errors. In addition, the thermal resistance to the ambient temperature must be high to maximize the diodes' signal output for reasonable input-drive levels. Finally, the thermal path within the mated resistor-diode pairs must provide efficient, low-loss heat transfer.

Although the circuit in **Fig 1c** is a straightforward extension of the configuration in **Fig 1b,** it's important to address the electrothermal design carefully in order to produce a practical monolithic circuit. These thermal considerations dominate the design and form of the circuit. **Fig 2** shows a simple electrical analog of the lumped thermal terms in the monolithic converter. The overall matching of these terms heavily influences the achievable performance. In particular, the die-attach thermal resistance dominates the thermal-impedance path. If this resistance is very high, the effects of mismatch in the other terms is minimal.

A practical electrothermal design

The use of separate, identical dies for the heater-diode pairs almost entirely eliminates thermal cross-coupling. This 2-die design eliminates cross-heating

The design of a monolithic rms/dc converter requires careful consideration of the electrothermal characteristics of the various elements in the IC's package.

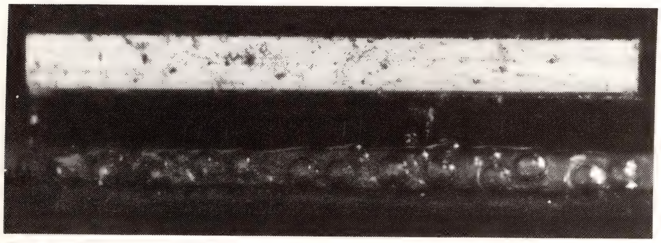


Fig 3—Bubbles are the secret ingredient *in the die bonding for the chips in an LT1088 rms/dc converter. An air-impregnated polymer provides the high die-to-ambient thermal resistance that the IC requires. The die's two distinct regions (light and dark) are the result of the scribe-and-break operation. The polymer die-attach process yields a thermal resistance that is not quite as high as that of the air-suspension technique but is much easier to implement.*

more effectively than any possible single-die approach could. A gain error, which you can correct by introducing a corresponding gain trim, comes from residual mismatches in thermal terms. The mismatches reflect die size, dissipation constants, and thermal-capacity differences. The most significant thermal-term mismatch arises from differing amounts and distribution of the die-attach material. The gain-correction trim involves altering the gain of the output stage in **Fig 1c.**

Because the die-attach resistance is so important (see **box,** "Construct your own thermal-resistance tester"), it demands careful consideration. **Table 1** gives the results for various die-attach methods. As you might suspect, suspending dies in free air offers the highest thermal resistance (although the approach is impractical). At the other extreme, standard eutectic bonding gives low thermal resistance but is easy to implement.

Another die-attach method, the use of an air-impregnated polymer, is nearly as good as air suspension and is practical to implement. The production technique that allows the use of air-impregnated polymer is called the OTT (oracular thermal transfer) process. **Fig 3** is a side view of a die that shows the bubbly polymer beneath the die. Large areas beneath the die are filled with air, and the result is the high thermal resistance noted in **Table 1.** The use of sufficient amounts of the die-attach polymer ensures a reliable die bond.

Fig 4 is a die photo of one heater-resistor/diode pair of the LT1088. The circular, concentric heater resistors promote evenly distributed, isothermal characteristics. The placement and aspect ratio of the heater rings are optimum for an even thermal flow across the die. The sensing diode is actually a parallel quad array located symmetrically about the die's center. This quad arrangement provides improved temperature-sensing characteristics as compared with a single device.

The LT1088's separate heater rings allow you to select either a 50 or a 250Ω input. Note that the IC contains only the basic thermal components needed to maintain isothermal conditions. The inclusion of support circuitry would introduce thermally based error terms and would therefore degrade performance.

Putting the converter to use

Once you've digested the operating theory and construction details of the LT1088, you can consider some practical applications of the IC. **Fig 5** shows a detailed circuit that uses the LT1088. **Table 2** gives typical performance specifications for the circuit. In **Fig 5**'s circuit, the power supply biases the temperature-sensing diodes. IC_1, set up as a differential servoamplifier whose gain is 9000, extracts the diodes' difference signal and biases Q_1. Q_1 drives one of the LT1088's heaters, thus completing a loop.

The 3300-pF capacitor gives the circuit a stable roll-off characteristic. The 1.5-MΩ/0.022-μF combination improves settling by reducing the gain during output slewing. Because of the square-law thermal gain of the LT1088, the overall loop gain is lower for small

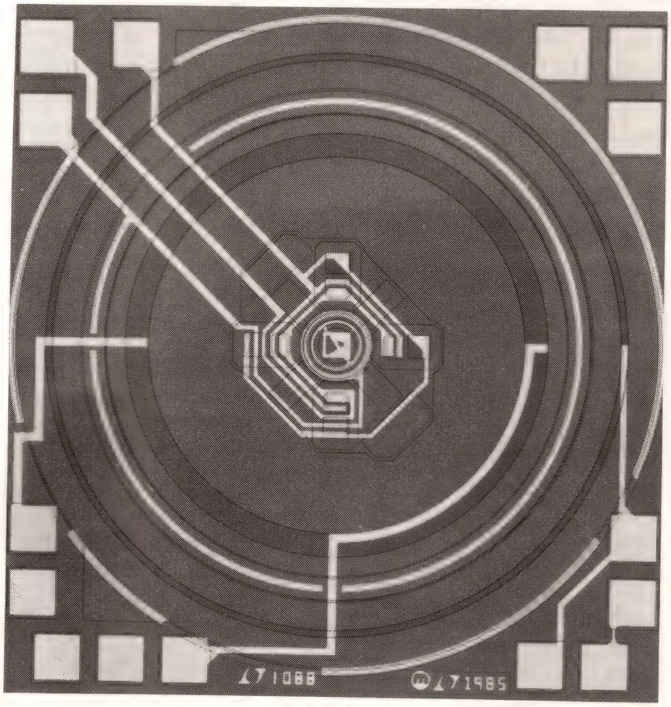


Fig 4—Concentric heater resistors and a quad diode array *make up the LT1088 rms/dc converter. The geometry of the heaters promotes even thermal flow across the die; the diode array is inside the heater rings, near the chip's center. By using appropriate pin connections, you can choose an input impedance of either 50Ω or 250Ω.*

Construct your own thermal-resistance tester

Establishing, maintaining, and verifying the proper thermal resistance between the LT1088 and its ambient surroundings is extremely important to the IC's operation. Because thermal resistance is a gain term, it must be constant with time, temperature cycling, and power level.

Low thermal resistance results in poor sensitivity to low-level inputs, hence a limited dynamic range. Thermal resistance that is too high causes excessive die heating, which leads to failure. Thermal crosstalk, the heat conduction between the two dies, must be as low as possible. Thermal conduction between the two dies lowers the available gain and thus degrades performance for low-level inputs.

Ensuring proper die-to-ambient and die-to-die thermal resistance requires an accurate measurement technique. **Fig A** shows a circuit that reliably measures thermal resistance. It works by supplying constant *wattage* to the LT1088's heater, regardless of the heater's resistance.

Although the heater's resistance changes as a function of the die temperature, the circuit must continuously control the V×I product applied to the heater. The circuit effects this control by measuring the heater current and forcing the voltage to keep the V×I product at a constant, calibrated value. The resulting temperature rise in the die, detected by the diode sensor, allows you to determine the thermal resistance.

IC_1, which measures the heater current across the 1Ω shunt, feeds the Y input of an analog multiplier. The multiplier's X input senses the differential voltage across the heater. IC_2 compares the multiplier's V×I-product output with a scaled, adjustable reference.

IC_2's output biases Q_1, thereby closing a loop around the heater. The 0.22-µF capacitor stabilizes the loop. To trim the circuit, insert a 50Ω, 1W resistor in place of the LT1088 heater. Next, adjust the 2-kΩ potentiometer so that the measured heater wattage (V across the heater times I through the 1Ω shunt) corresponds to the voltage at the potentiometer's wiper. The scale factor is 10Ω/W. Disconnect the 50Ω resistor, and the circuit is ready for use.

To measure thermal resistance, adjust the wattage control to obtain 350 mW, place the switch at 25°C, and read the diode's voltage. Then, switch to the Hot position and read the diode's voltage after it settles. Assuming that the diode's temperature coefficient is 1.8 mV/°C, calculate the thermal resistance in °C/W. You measure thermal crosstalk the same way, except that the sensing diode and heater are not on the same die.

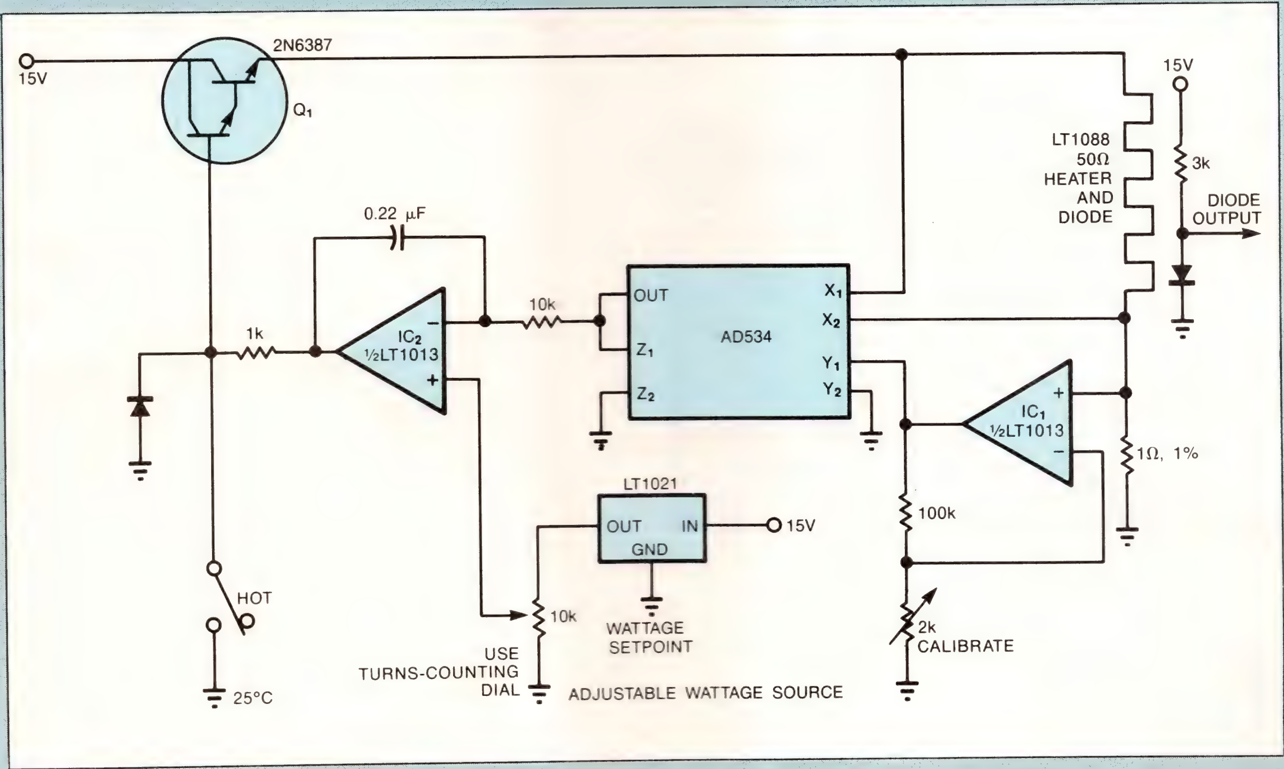


Fig A—You can construct your own thermal-resistance tester. *This circuit allows you to measure an LT1088's die-to-ambient and die-to-die thermal resistance. It operates by keeping the IC's heater power to a constant level, regardless of the heater resistance's changes with temperature. The circuit is easy to calibrate and use.*

inputs. This nonlinear gain characteristic would normally result in slow settling for input values below about 10 to 20% of full scale. The LT1004/1-kΩ/3-kΩ network, however, provides a simple breakpoint, thereby boosting gain in this low-level region to improve settling.

IC_2, a trimmable-gain output stage, serves to compensate for gain variations in the two sides of the LT1088. To trim the circuit, apply a dc signal that's approximately 10% of full scale to the input (for example, 1V for the 250Ω range, 500 mV for the 50Ω range.) Adjust the zero trim so that $V_{OUT}=V_{IN}$. Next, apply a full-scale dc input and set the full-scale trim to yield that value at the output.

Repeat the trims until both the zero trim and the full-scale trim produce outputs whose accuracy is well within 1% of full scale. In an alternative trim scheme, you can apply no input, ground Q_1's base, and set the zero trim until IC_1's output is active. Then apply a full-scale input and trim the full-scale adjustment to

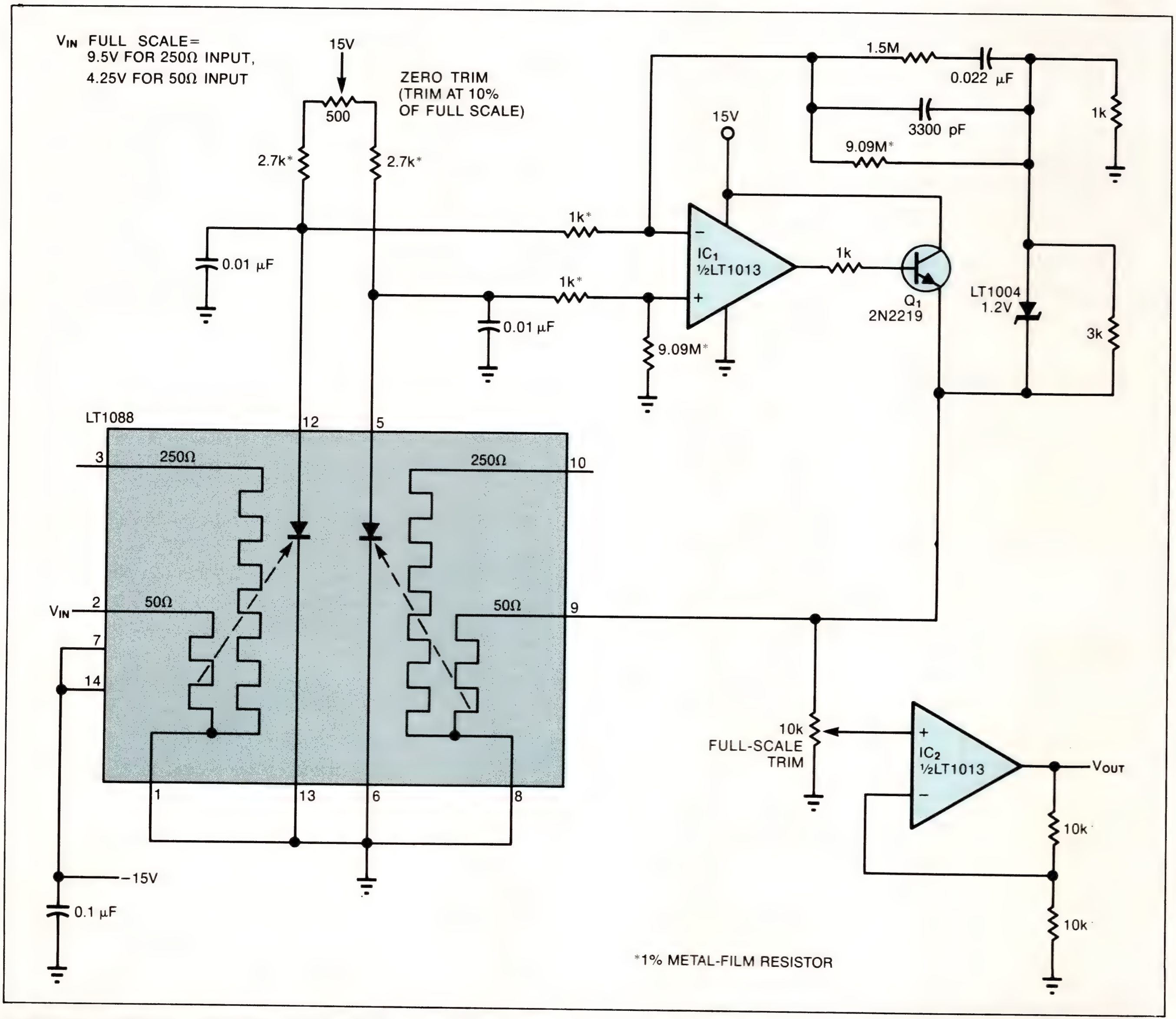


Fig 5—Basically a servoamplifier circuit, *this configuration allows you to extract a dc voltage from the LT1088; this voltage corresponds to the rms value of* V_{IN}. *The circuit incorporates a number of tricks to improve settling and to compensate for the nonlinear, square-law thermal gain of the LT1088. You can trim the circuit to obtain accuracy that's well within ±1%.*

To take full advantage of a monolithic rms/dc converter, you should use external support circuitry that compensates for the IC's nonlinear thermal-gain characteristic.

obtain the full-scale value at the output.

At frequencies greater than 10 MHz, input connections to the LT1088 require care. Parasitic inductance builds up rapidly in wire runs, so you should connect the IC's input heater lead *directly* to the source being measured. It's also wise to shield the input line from the rest of the circuit. **Fig 6** shows one way to implement this shielding. A simple copper RF shield isolates the circuitry from the input. The LT1088's mounting is such that the input pin is as close as possible to the input-connector pin.

An additional precaution is to mount the 0.01-μF capacitors in **Fig 5**'s circuit directly at the LT1088's package. These capacitors minimize the effects of RF pickup by the temperature-sensing diodes.

Another layout concern involves thermal considerations. Because the LT1088's operation depends on thermal symmetry, the IC is sensitive to external temperature gradients. This sensitivity is a particularly important factor in the case of small inputs, which force the device to operate at temperatures close to the ambient temperature. You should, therefore, mount the LT1088 in an area that's isothermal and free of drafts. Keep power-generating components away from the IC, and exercise particular caution in fan-cooled equipment. Under normal conditions, you need no thermal baffle or enclosure. Under no circumstances should you use a heat sink.

Plot the IC's performance

Fig 7 shows a plot of error vs input frequency for an LT1088 operating under the condition of a full-scale input to the 50Ω input pin. Be advised that no bandwidth degradation occurs for lower input levels. References for the measurement were Fluke Model 540B thermal-transfer standards used in conjunction with A-55 converters. The references were certified to 50 MHz. (They also provided data for frequencies greater than 50 MHz, however. The accuracy of certified refer-

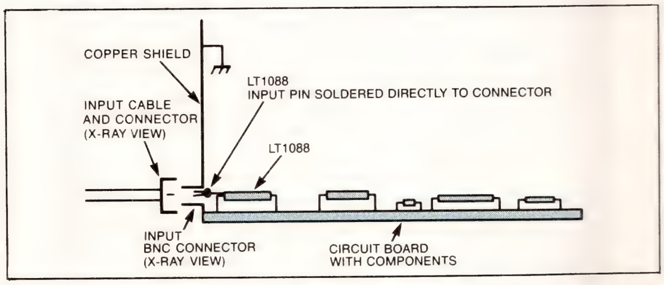


Fig 6—Take special care when you drive the LT1088 at high frequencies. *First, make sure that the RF-input line to the IC's heater is as short as possible. Next, try to shield the input from the rest of the circuit. Finally, mount the LT1088's bypass capacitors as close as possible to the IC package. Be sure to keep heat-producing components well away from the LT1088, and never, never use a heat sink with the device.*

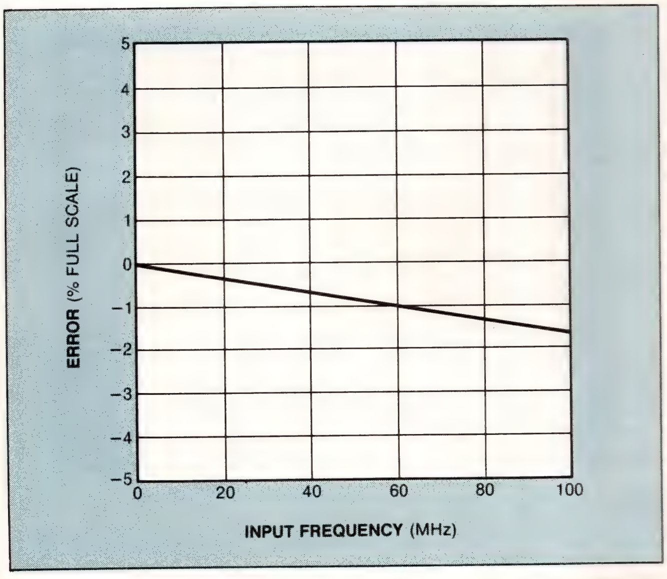


Fig 7—Output error is less than 2% at frequencies to 100 MHz *for the LT1088 rms/dc converter. For this curve, a full-scale input drives the IC's 50Ω input. Because the LT1088 responds only to the heating value of an input voltage, it's insensitive to either the frequency or the crest factor of a waveform.*

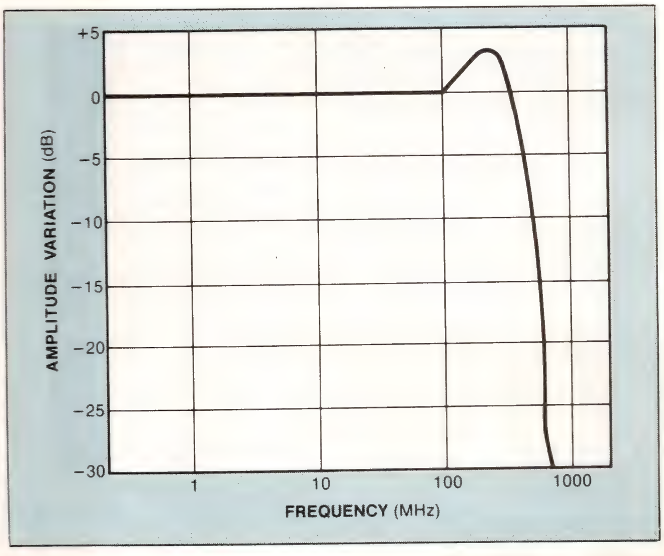
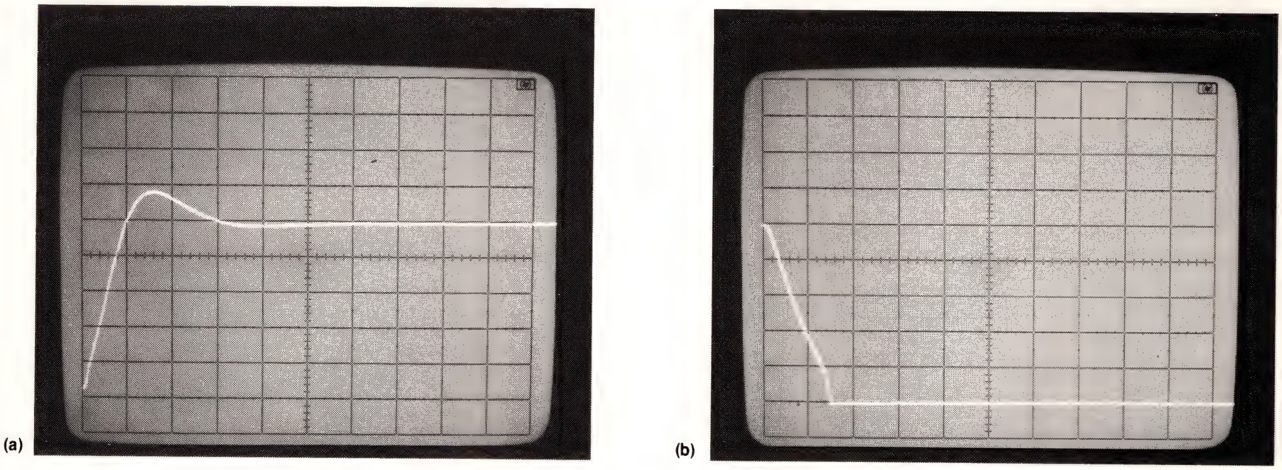


Fig 8—Usable at frequencies well above 100 MHz, *the LT1088 exhibits some peaking in its roll-off characteristic. This curve reflects the application of an RF input to the 50Ω heater; if you use the 250Ω heater, the response rolls off at approximately 20 MHz. Bond-wire inductance and heater-diode capacitance are the causes of the high-frequency roll-off.*

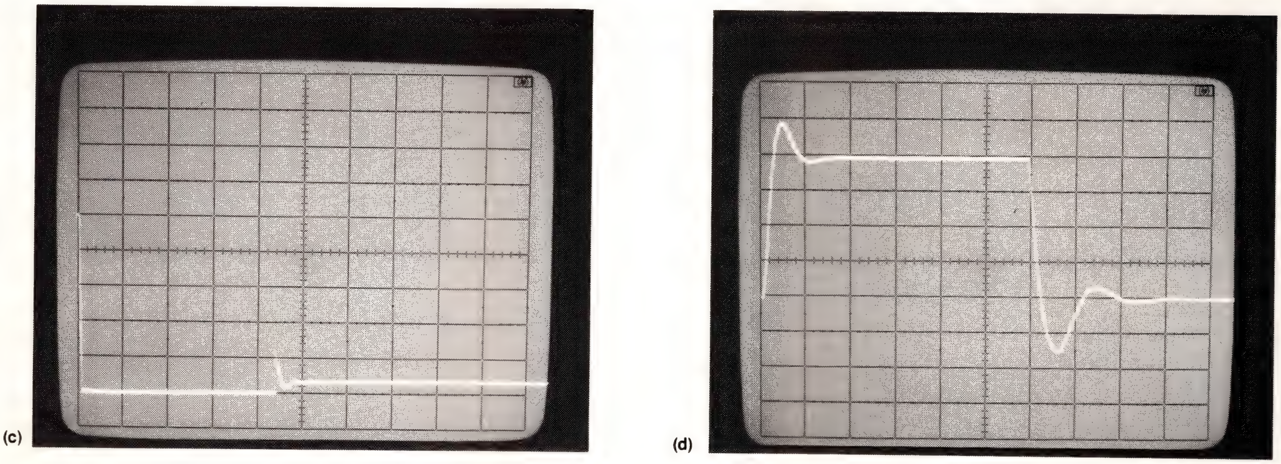
ences of this type is usually well within the listed tolerances, so, in all probability, the data is valid even at the higher frequencies.)

Fig 8 shows a similar plot that extends to a higher frequency range. Unfortunately, equipment and test-setup limitations introduce uncertainties at the highest frequencies, but the data most probably approximates the actual performance of the LT1088. The peaking followed by the steep roll-off most likely comes from the LT1088's high-frequency limitations. In particular, bond-wire inductance becomes increasingly significant as frequency increases.

Also, capacitance between the heater and the sensing diode permits RF pumping in the diode, which almost



VERTICAL	HORIZONTAL
2V/DIV	50 mSEC/DIV



VERTICAL	HORIZONTAL
2V/DIV	1 SEC/DIV

Fig 9—The step response of the rms/dc converter *depends on the servoamplifier's roll-off. The trace in **a** reflects a full-scale, positive-going input step to the 250Ω heater; **b** shows the negative-going response. The trace in **c** is an expanded version of the one in **b**; the anomaly that occurs after five seconds is the result of saturation in the servocircuit. The trace in **d** is the result of keeping the LT1088's input within the specified operating range.*

In using an rms/dc converter to convert high-frequency signals, you must keep the input line short, and you should provide shielding for the input line.

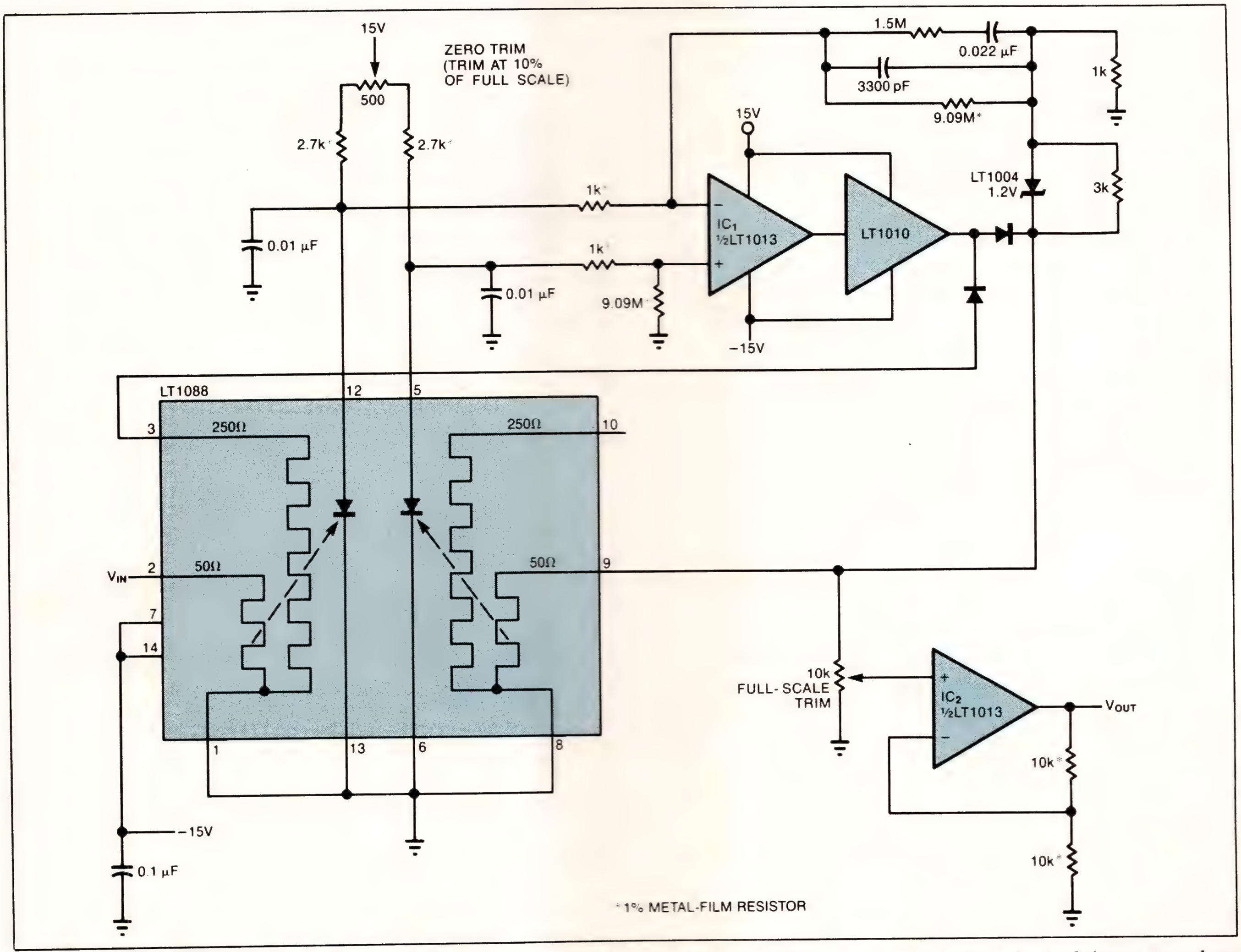
certainly causes deleterious results. The 250Ω range lowers the 1%-error frequency. The described parasitics combine with the higher input-voltage swing for this range to limit the 1%-error bandwidth to about 20 MHz.

Loop time constants limit the low end of the LT1088's useful frequency spectrum. For the values given in **Fig 5**, the circuit begins to follow the input at frequencies lower than about 50 Hz. Lower-frequency operation requires that the loop have longer time constants (for example, by increasing the value of the 3300-pF capacitor), but the circuit's settling time then increases.

The circuit's crest-factor performance depends on the IC's breakdown limits and the usable low-input-power range. Breakdown limits are a function of IC processing. The usable low-input-power range reflects a basic signal-to-noise conflict. Low input power produces small amounts of signal. These low levels make it difficult for the circuit to discriminate accurately between desired inputs and ambient thermal phenomena.

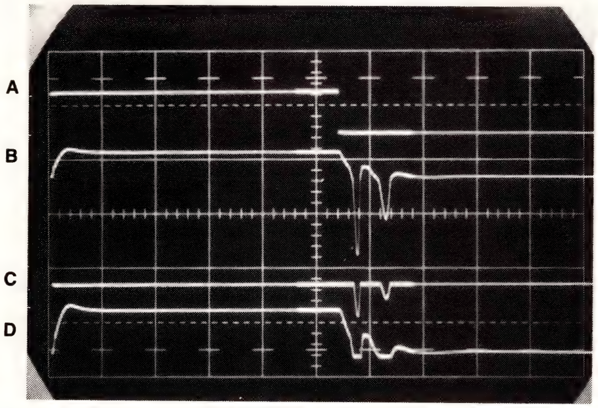
Response to a step

The circuit's step response is a function of the servo-electronics' roll-off. **Fig 9a** shows the response for a full-scale input step to the 250Ω heater. You can see that the loop response is nicely damped. The small glitching at the beginning of the step comes from the gain breakpoint in IC_1's feedback loop. **Fig 9b** shows the



*1% METAL-FILM RESISTOR

Fig 10—You can improve the settling time of an rms/dc converter *by using this circuit. This setup speeds settling by applying an open-loop heating correction whenever a thermal imbalance occurs. Diode steering at the buffer's output sinks current from the 250Ω input heater and thus improves settling time by compensating for the thermal imbalance.*



TRACE	VERTICAL	HORIZONTAL
A	5V/DIV	20 mSEC/DIV
B	10V/DIV	20 mSEC/DIV
C	20V/DIV	20 mSEC/DIV
D	5V/DIV	20 mSEC/DIV

Fig 11—These traces, the result of using Fig 10's settling-acceleration circuit, *show that the rms/dc converter can settle quickly. The negative-going input (trace A) causes a servoamplifier to slew (trace B). A buffer amplifier sinks current (trace C) from the LT1088's heater. Trace D shows the converter's settling characteristic.*

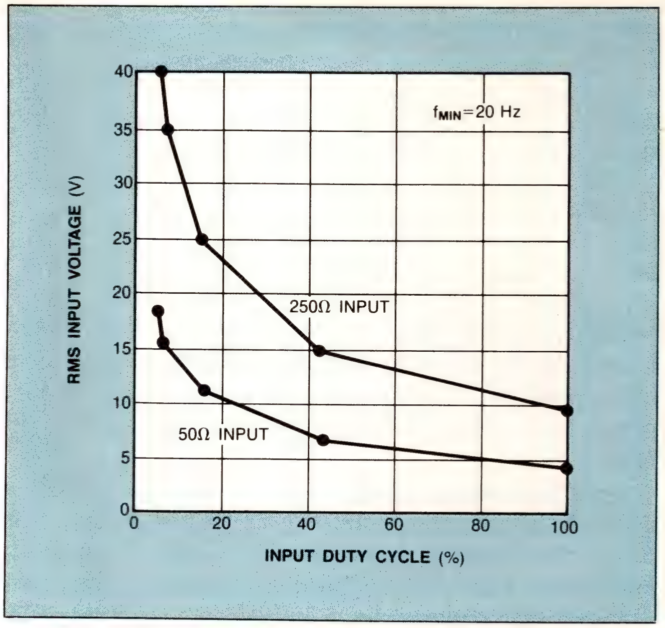


Fig 12—Take care not to overdrive the LT1088's heaters. *These curves give the safe operating limits for the IC. The curves define the maximum safe rms input voltage as a function of the waveform's duty cycle. You must keep the device's input power to 375 mW max; otherwise, damage to the heaters could result.*

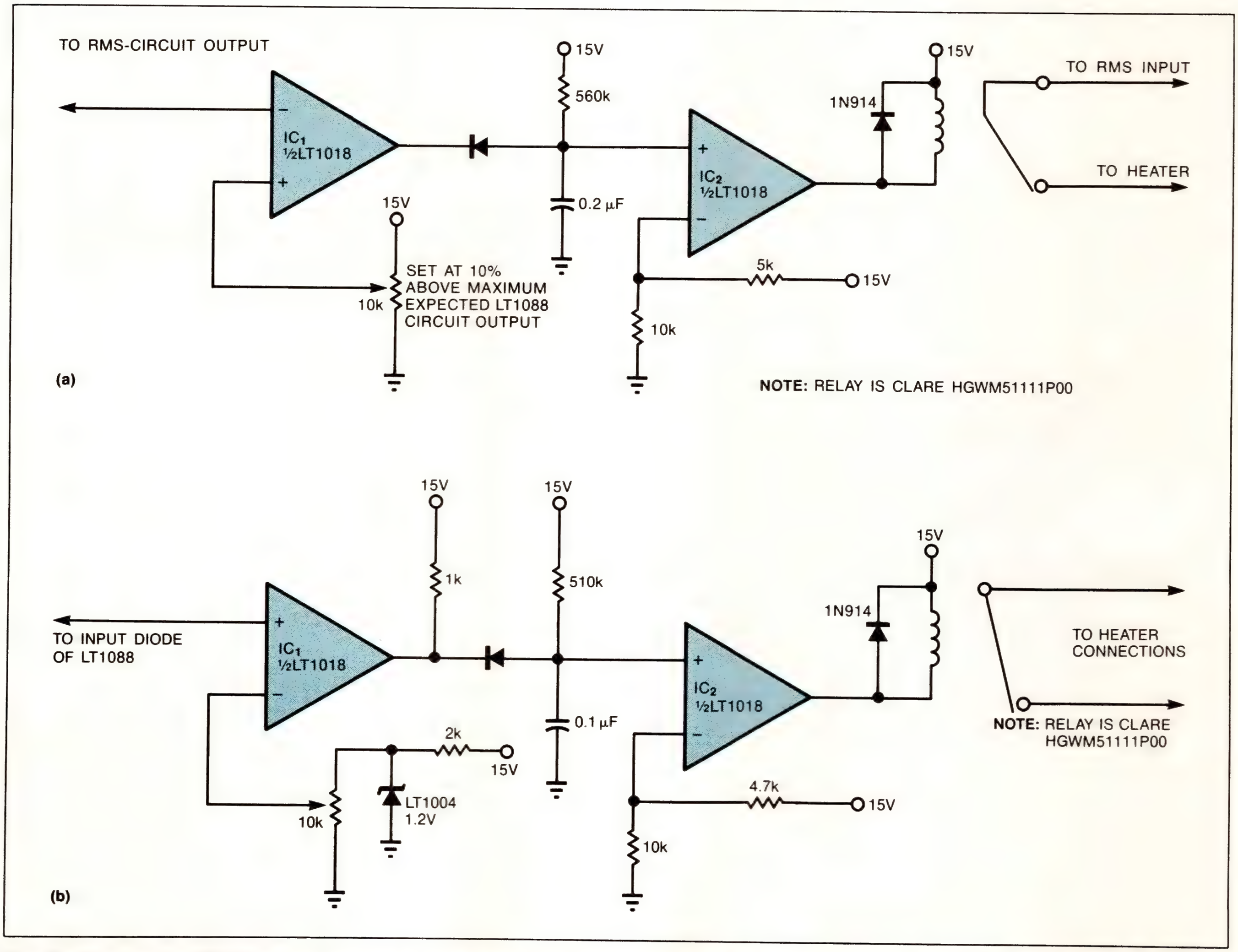


Fig 13—Protect the LT1088's input heaters against overloads. *The circuit in* ***a*** *senses the output of the servoamplifier in* ***Fig 5;*** *when an overload occurs, the circuit breaks the input connection to the heater circuit. The diode-sensing circuit in* ***b*** *responds to overloads much more quickly than the one in* ***a,*** *but it requires a trimming step.*

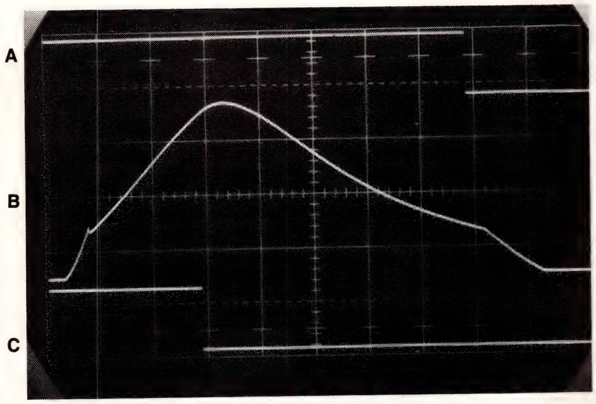
The low input impedance of the monolithic rms/dc converter sometimes requires you to provide a buffer amplifier to drive the IC's input heater.

negative-going step. Although the response appears to be clean (again, note the gain-breakpoint glitch), **Fig 9c** shows that the loop's output comes to a new value well after it appears to have settled.

Fig 9c is actually a slower version of **Fig 9b.** (The initial negative-going step is just visible at the extreme left in **Fig 9c**). Almost five seconds after settling apparently occurs, the loop's output abruptly assumes a new value—the loop had been in saturation during the first five seconds. Exceeding the allowable low-range operating area (defined by the dynamic-range spec) forces the servo into saturation. The saturation causes thermal imbalances in the LT1088, which in turn cause the 5-sec delay before the loop becomes active again.

As stated, some applications can drive the LT1088 outside its operating range and thus force thermal imbalances. If you require fast settling, you'll find **Fig 10's** circuit useful. This configuration speeds settling by applying an open-loop heating correction when thermal imbalance occurs. When the input (**Fig 11,** trace A) is a negative-going step, IC_1's output (trace B) slews.

Loop delays cause IC_1 to overshoot, turning off the heater drive and thermally imbalancing the LT1088. Diode steering at the output of the LT1010 buffer sinks current from the 250Ω input heater (trace C). This current produces heating and tends to compensate for the thermal imbalance, thus reducing settling time.



TRACE	VERTICAL	HORIZONTAL
A	10V/DIV	5 mSEC/DIV
B	2V/DIV	5 mSEC/DIV
C	10V/DIV	5 mSEC/DIV

Fig 14—These waveforms result from using the heater-protection circuit in Fig 13b. *Excessive drive (trace A) to the heater forces the servoamplifier to slew (trace B). A relay switches (trace C) and removes heater drive in about 15 msec.*

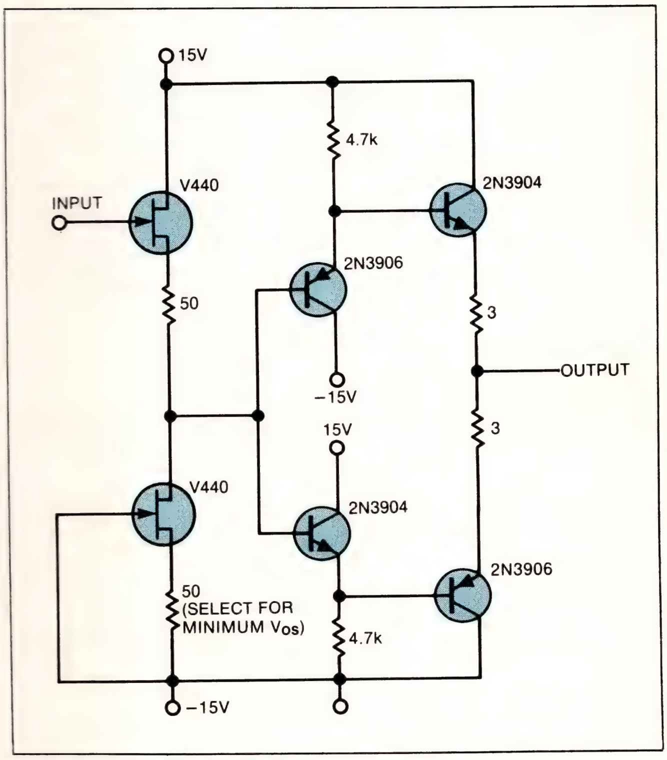


Fig 15—If you need a buffer for the LT1088's low-impedance input, *use this unity-gain circuit; it provides a high input impedance and a bandwidth of about 25 MHz. The buffer's slewing and bandwidth characteristics appear in* ***Table 3.***

IC_2's output (trace D) settles fairly quickly after it recovers from the open-loop correction.

The scope photo in **Fig 9d** shows the circuit's response when the input stays within the specified operating range. Settling on both edges is clean, and the loop's output quickly assumes and maintains its final value. In any study of the LT1088's dynamics, you must consider that, although the output voltage has settled, the IC's internal die temperature may still be moving toward its final value. When you observe the LT1088's operation, it's important to distinguish between voltage dynamics and thermal dynamics.

Excessive heater drive is the principal cause of LT1088 failures. The IC's input power at 25°C is specified at a continuous 375 mW; it also permits 30-sec excursions to 435 mW. At temperatures above 25°C, you must derate these figures by 3 mW/°C. **Fig 12** plots safe operating limits for input duty cycle vs input voltage. Accidental heater overdrive can damage or destroy the LT1088. In situations in which overdrive might occur, you should employ some form of heater protection.

Be careful not to overdrive the converter's input heater; in cases in which an overvoltage condition could occur, it's best to connect an overload-protection circuit.

Fig 13a shows a heater-protection circuit that responds quickly enough to prevent damage from most overloads. IC_1's input connects to the output of the LT1088 servocircuit shown in **Fig 5.** If the servocircuit's output exceeds the threshold at IC_1's other input, IC_1 trips and discharges the 0.2-μF capacitor. The resulting drop in voltage causes IC_2's output to switch low, energizing the relay and breaking the heater circuit.

The 560-kΩ resistor provides a long recharging period for the capacitor, thus preventing chattering. The circuit's response is limited by the rms circuit's slew rate, which is about 0.2V/msec. For reasonable overloads, the LT1088's temperature increases at the rate of approximately 1°C/msec. A 10V step at the LT1088 takes about 50 msec to slew; the result is a temperature rise of about 50°C.

Severe overloads cause faster heating, however, and in such a case, **Fig 13a's** circuit might not act quickly

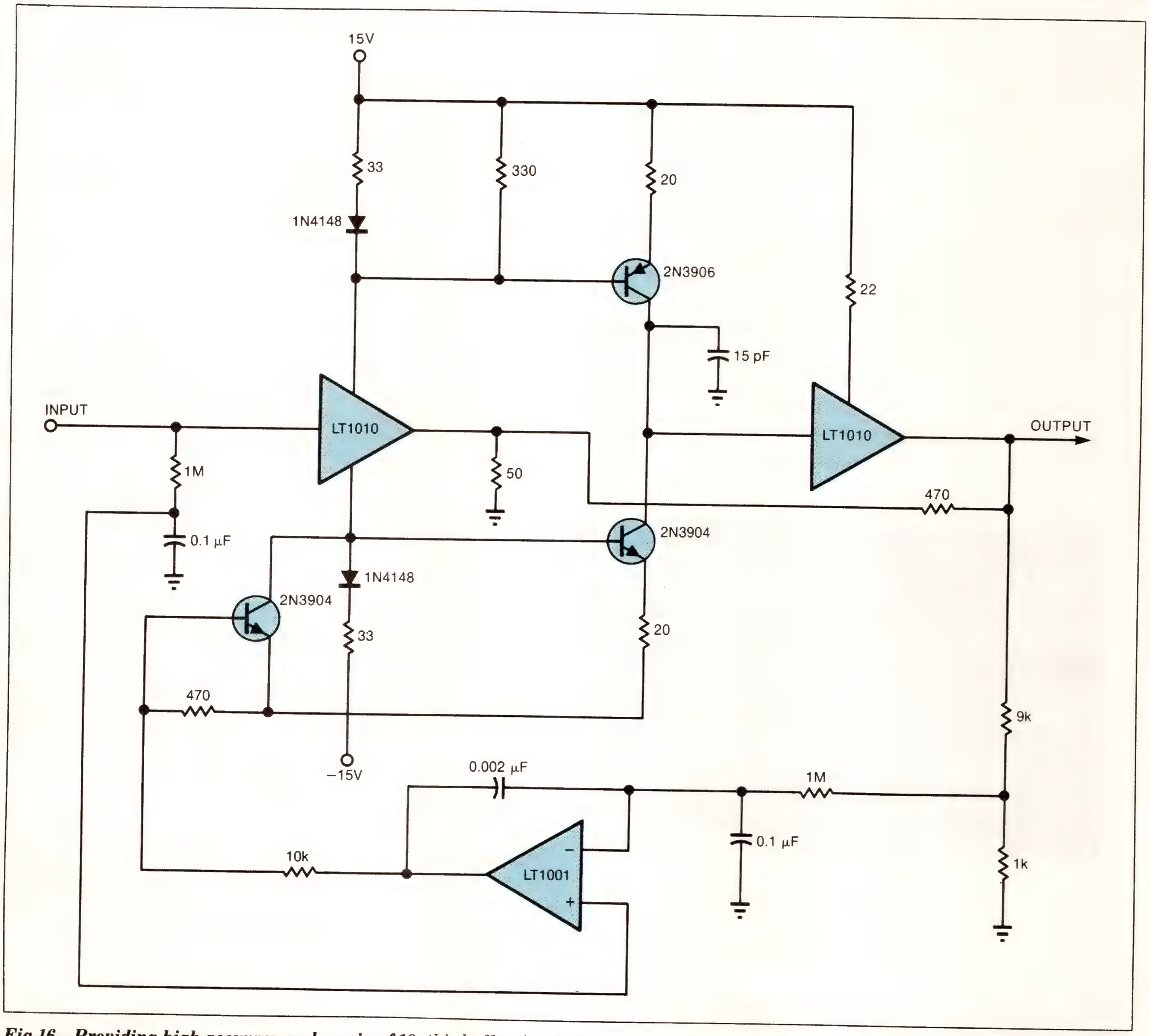
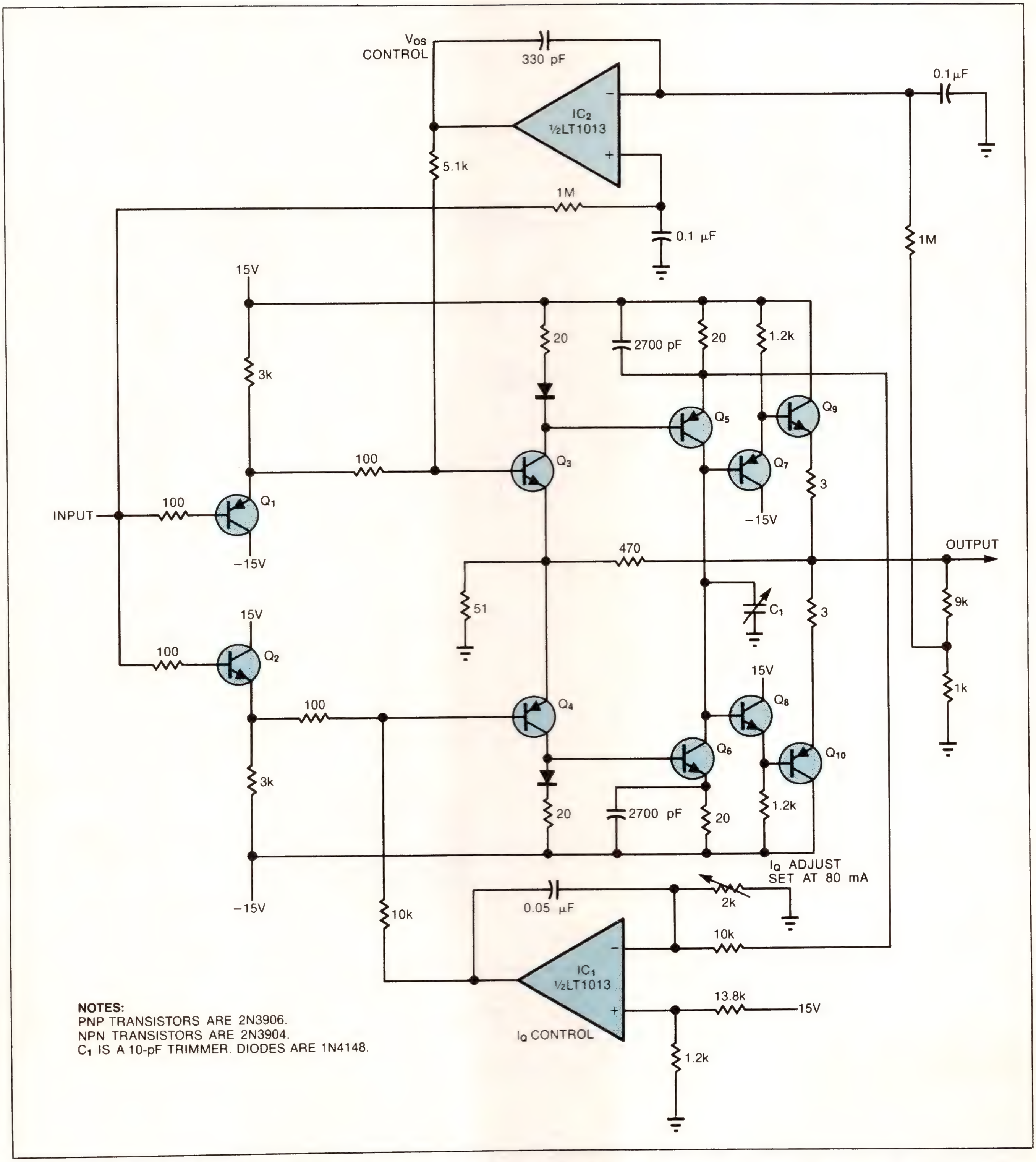


***Fig 16—Providing high accuracy and a gain of 10,** this buffer circuit is suitable for driving the LT1088 rms/dc converter. The circuit's not a speed demon; as you can see in **Table 3,** it slews at 100V/μsec and has a 2-MHz bandwidth.*



NOTES:
PNP TRANSISTORS ARE 2N3906.
NPN TRANSISTORS ARE 2N3904.
C$_1$ IS A 10-pF TRIMMER. DIODES ARE 1N4148.

Fig 17—If you need both high speed and a gain of 10, *use this buffer circuit; although it's complex, it's equal to the task. As you can see from* ***Table 3,*** *the circuit slews at 3000V/µsec and has a 32-MHz bandwidth. The buffer easily drives an LT1088's 50Ω input.*

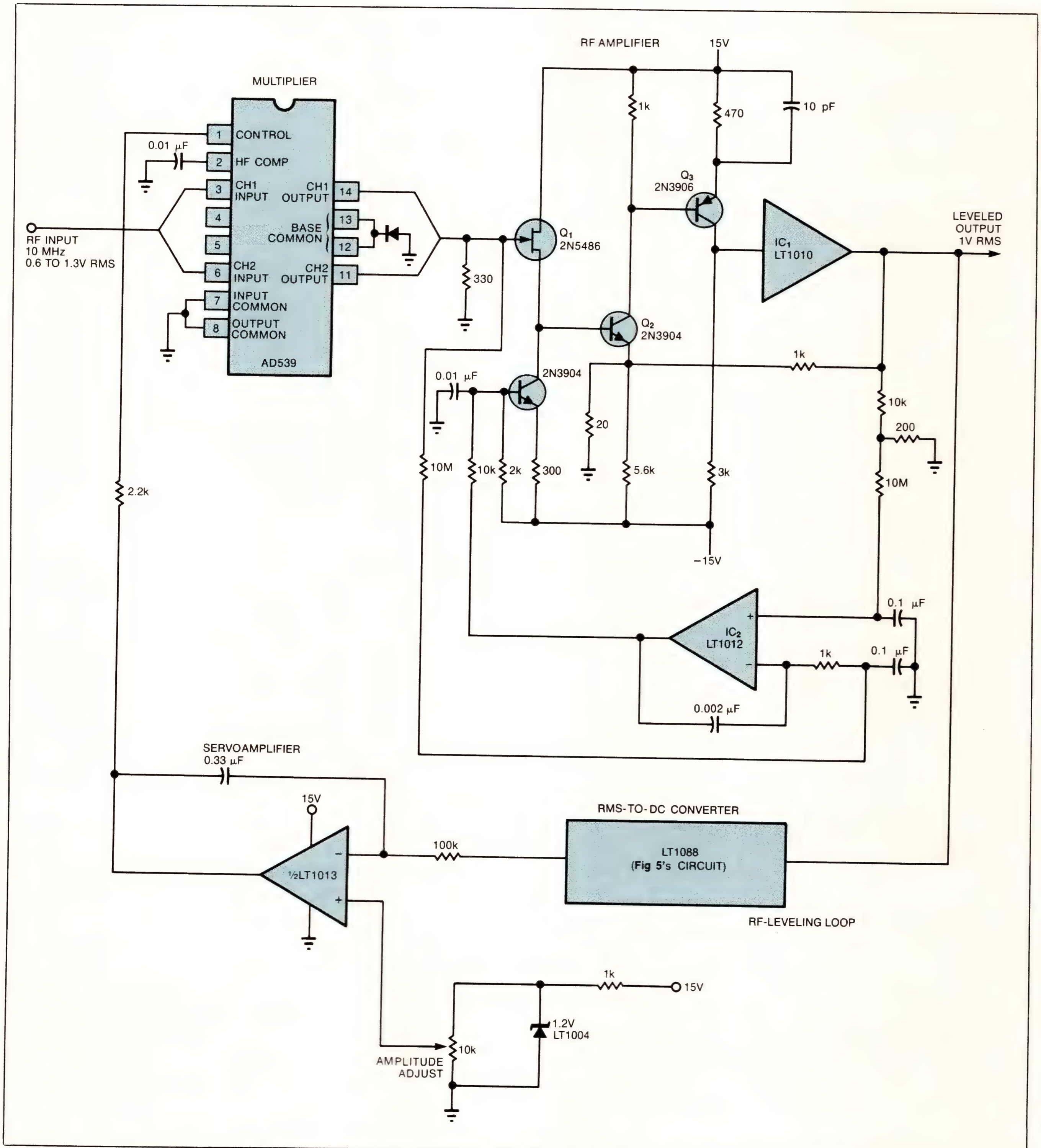
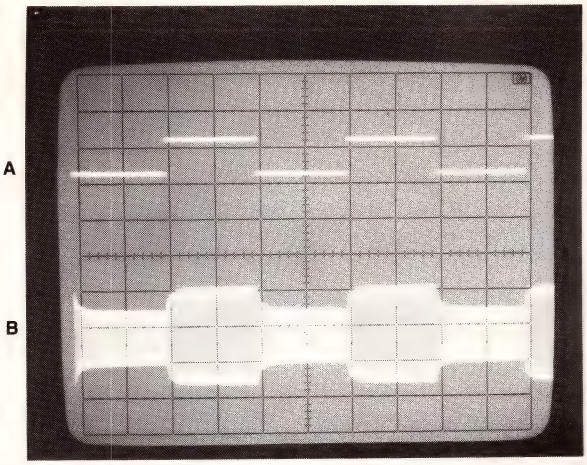


Fig 18—This configuration, an effective automatic-gain-control circuit, *is an RF leveler. The circuit holds the RF output constant at 1V rms, regardless of changes in load, input voltage, power-supply voltages, and other variables. The heart of the circuit is the LT1088 rms/dc converter.*



TRACE	VERTICAL	HORIZONTAL
A	0.5V/DIV	500 mSEC/DIV
B	1V/DIV	500 mSEC/DIV

***Fig 19—The response characteristic of Fig 18's circuit** is clean and fast. A step-function voltage (trace A) applied to the servoamplifier's RF-setting input produces the RF-level response in trace B. The RF assumes its new level in about a second.*

enough to prevent damage. The circuit in **Fig 13b** is faster, but it requires a trim. It works by directly sensing the temperature of the LT1088, instead of using the servoamplifier's output. The action of **Fig 13b's** circuit is similar to that of **Fig 13a's** circuit, except that the input comes from the LT1088's input temperature-sensing diode. **Fig 14** shows waveforms for the circuit in **Fig 13b**.

Excessive drive (trace A) to the LT1088 forces the servoamplifier (trace B) to slew. The sensing diode, responding more quickly than the servo, causes the circuit to switch the relay (trace C), removing the heater drive in 15 msec. Because the loop responds after the temperature change, the servoamplifier's output peaks at only 6V, about one-third of the input step. Because of initial diode tolerances, this circuit has the disadvantage of requiring a trim. To effect the trim, measure the diode's output at 25°C and set IC_1's negative input to the desired temperature-cutoff point. Assume that the diode temperature coefficient is −1.8 mV/°C.

Some applications might require a buffer to drive the LT1088's relatively low input impedance. It's not easy to provide such a buffer if you want to preserve the converter's large bandwidth and high accuracy. However, by using an LT1010 buffer, you can achieve bandwidths in the low megahertz region. The circuit in **Fig 15**, using a FET input and a complementary emitter-follower design, extends the bandwidth to 25 MHz.

If you need a buffer that has gain, use the circuit in **Fig 16**, which provides low-megahertz performance at a gain of 10. Although it's complex, the design in **Fig 17** has a 32-MHz bandwidth at a gain of 10. For detailed discussions of these three buffers, see **Ref 1. Table 3** summarizes the buffers' performance.

One application that exploits rms/dc conversion is an RF-leveling loop. **Fig 18** shows a loop that operates at 10 MHz. The RF input connects to the AD539 wideband multiplier. The multiplier's output drives an RF amplifier. The discrete transistors provide gain, and the LT1010 serves as an output buffer. The LT1012 provides dc stabilization for the stage (for operating details of this stage, see **Ref 2**). The LT1088-based rms/dc converter converts the RF amplifier's output to a dc voltage.

A servoamplifier compares the LT1088's output with a settable dc reference and biases the multiplier's control channel, thereby completing a loop. The 0.33-μF capacitor provides frequency compensation by rolling off the gain at a frequency well below the response of the LT1088 servo. The circuit rejects changes in load, input, power-supply voltages, and other variables. **Fig 19** shows the loop response (trace B) to a step-function test signal (trace A) injected at the servoamplifier's positive input. The response is clean; settling occurs in about a second. **EDN**

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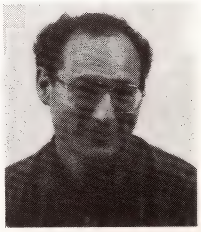
Author's biography



Jim Williams, staff scientist at Linear Technology Corp (Milpitas, CA), specializes in analog-circuit and -instrumentation designs. He has served in related capacities at National Semiconductor Corp, Arthur D Little Inc, and the Instrumentation Development Lab at MIT. A former student of psychology at Wayne State University, Jim enjoys tennis, art, and collecting antique scientific instruments.

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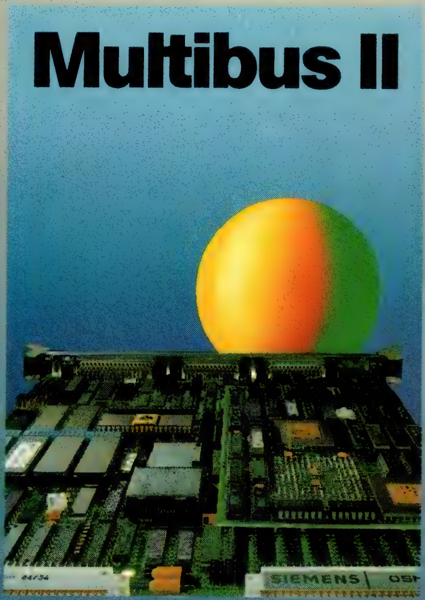

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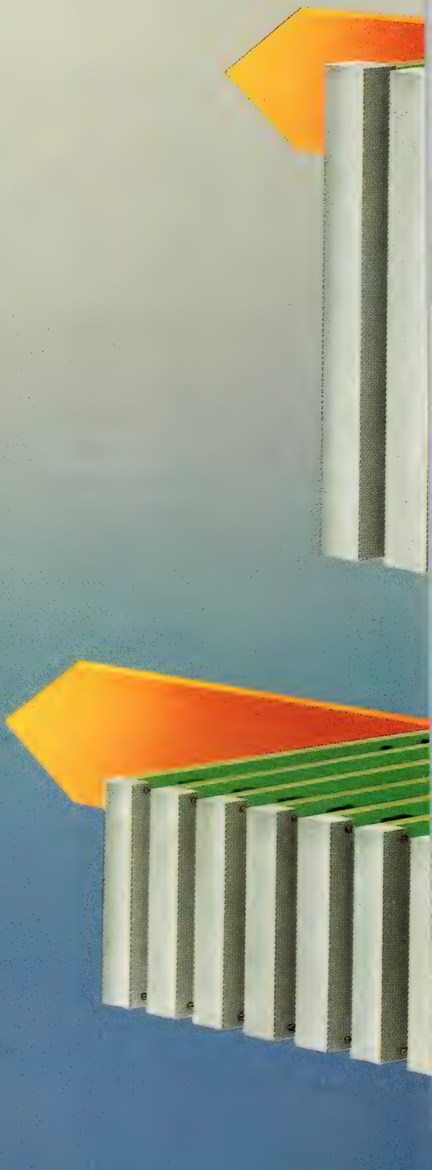

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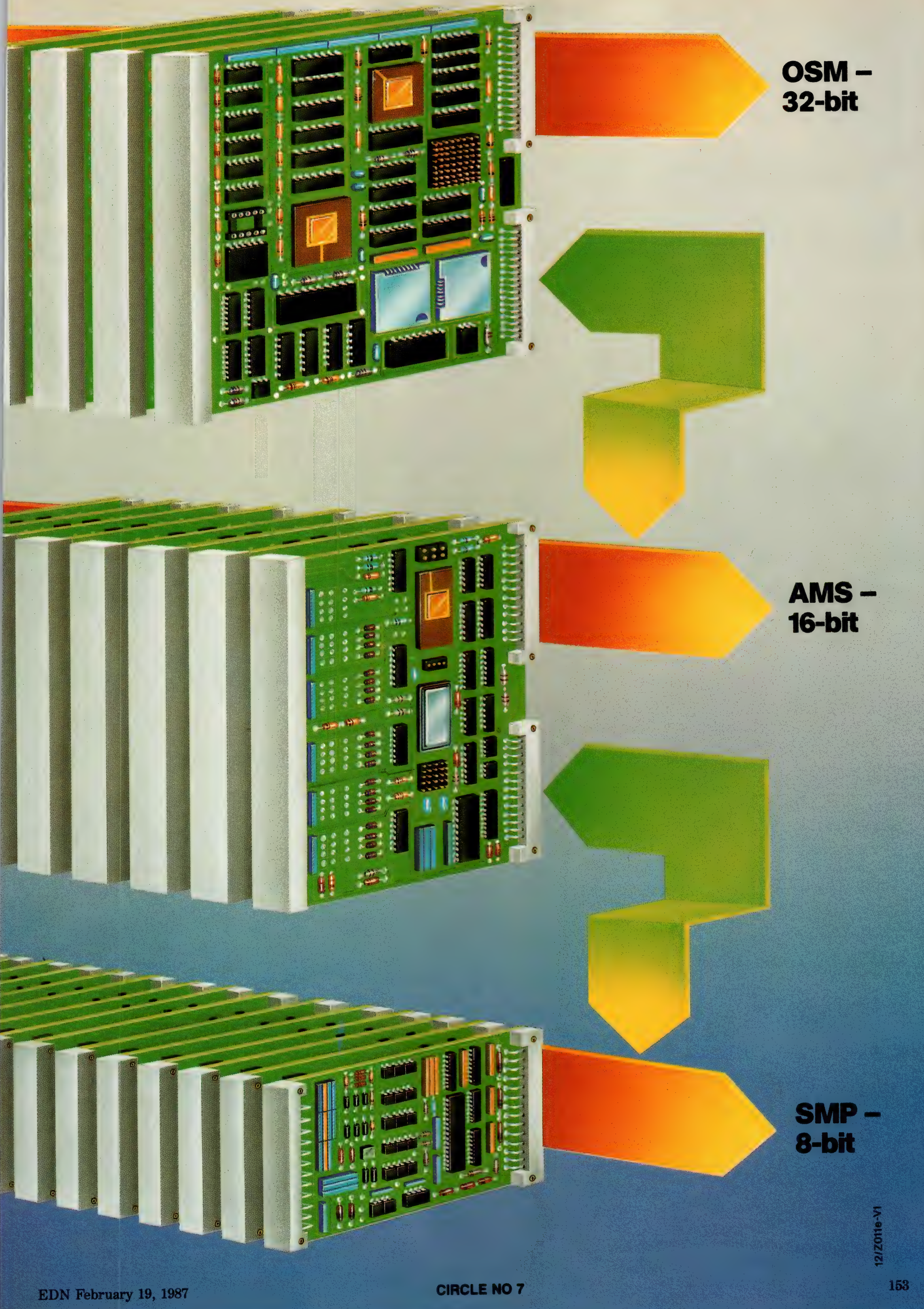

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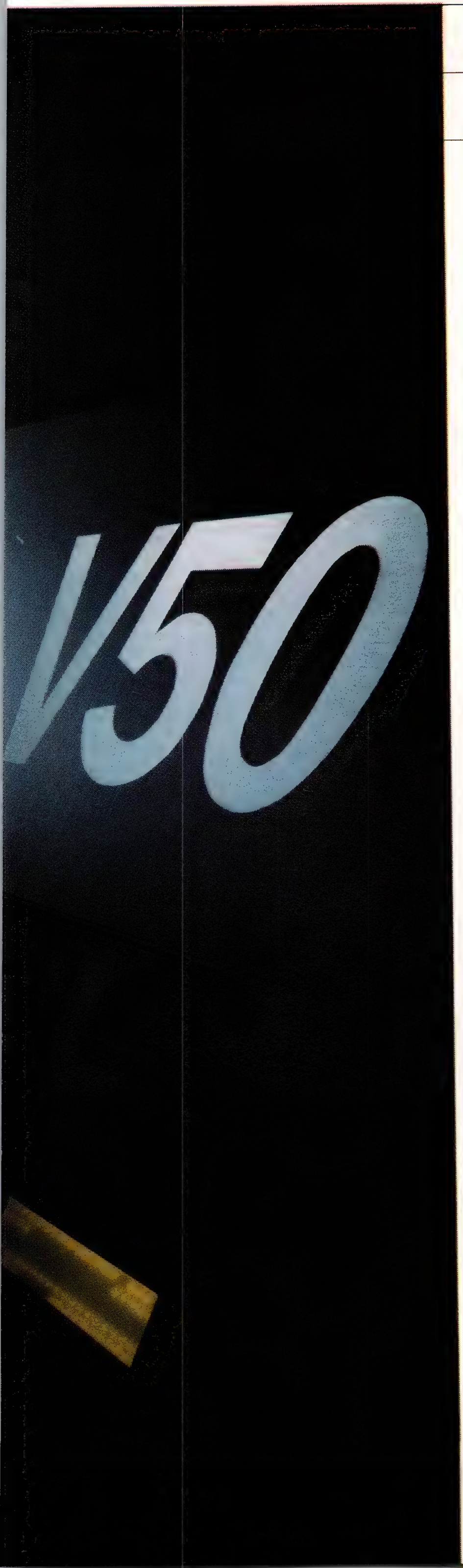

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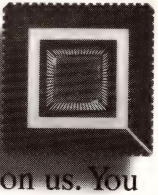

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Compiler allows Ada development on an IBM PC/AT

You can now obtain an Ada compiler for the IBM PC/AT that provides all the features of the language and has been validated by the Department of Defense. What's more, the compiler doesn't just meet specifications; it allows you to solve real programming problems.

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For $3000 you receive one single-slot, fully populated, 4M-byte RAM board with parallel and serial ports, six 1.2M-byte floppy disks containing the compiler, and sample Ada programs amounting to 1.2M bytes. The documentation consists of one installation manual; one *1983 ANSI/MIL-STD-1815A Language Reference Man-*

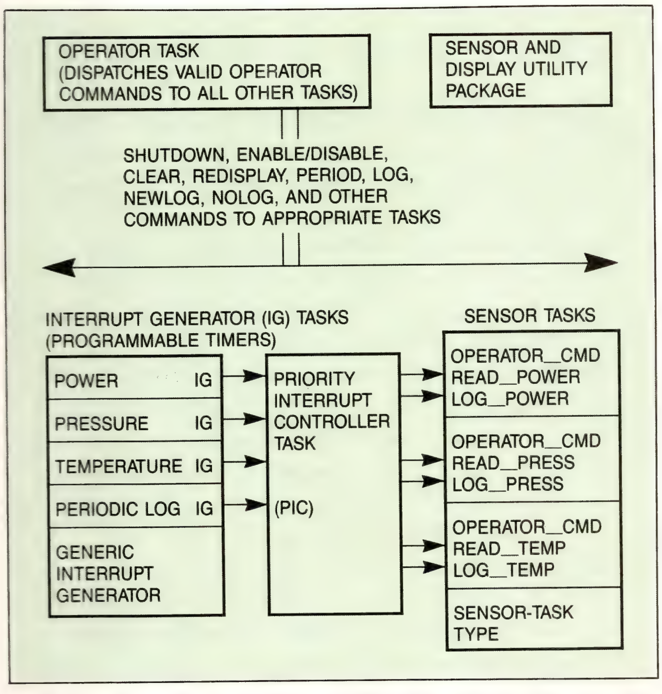


***Fig 1—The CCCP includes nine real-time tasks** that test the adequacy of the Alsys Ada compiler as a tool for solving real programming problems.*

(Ed note: The opinions expressed in this article are those of the author and do not necessarily reflect the views of Draper Lab.)

Because of the size and scope of the Ada language, the big question is, can you solve real programming problems with an IBM PC/AT-based system?

ual; one user's manual for compiling, linking, and interfacing with other languages; and a 114-page application developer's guide.

Because of the size and scope of the Ada language, the big question is, can you solve real programming problems with this system? The president of Alsys is J Ichbiah, the leader of the Ada language design team, so you can be confident that Alsys Ada obeys Ada language semantics. DoD validation, though necessary, is not an adequate test for convenience, ease of use, and simplicity of procedure. No one validation test suite could cover all permutations of language features or memory allocation models contained in real problems. In addition, the DoD validation suite makes no attempt to measure performance or efficiency. Consequently, an auxiliary test suite of application programs covering tasking, networks, controllers, databases, and number-crunching will help determine how well the package meets your needs in developing real-time, tasking software for embedded controllers.

The job of testing the Alsys system is an easy one, because the Alsys Ada compiler, a 300,000-line Ada program, can compile itself. You can therefore be certain that access types, discriminated records, recursion, abstract data types, packages, and most nontasking features—all of which are vital to the operation of the compiler—are already thoroughly tested by the compilation process. You'll only need to verify the correct operation, in a nontrivial application program, of tasking, tasking with generics, TEXT_IO packages, and other Ada features not found in the Ada compiler itself.

Glossary of Ada terms

The following list gives brief definitions of Ada terms used in this article. It constitutes only a subset of all Ada terminology.

- **Access type**—the Ada term for pointers.
- **Entry call**—one Ada task calling another Ada task.
- **Family of entries**—an entry call that's indexed by a parameter.
- **Generic**—an Ada facility that can do macro preprocessor expansions of generic subprograms into specific instances of a subprogram.
- **Instantiation**—the act of performing a macro-like expansion of a specific subprogram or package into a specific form of the subprogram or package.
- **Package**—the encapsulation of related subprograms, global storage, useful types, and operators in one unit. Roughly equivalent to a well-thought-out Fortran or C subroutine library with optional global variables and internal static and dynamic variables.
- **Pragma**—a reserved word that allows compiler directives to be given to the compiler.
- **Representation clause**—high-level syntax that allows you to access a machine directly.
- **Tasking**—the Ada construct that allows for concurrent processing.
- **Type marks**—the equivalent of C type specifiers and Fortran types.
- **Variant structure**—a more advanced form of the C structure with embedded C unions, or a mechanism that's loosely related to Fortran equivalence. A parameterized record whose structure can be changed according to the value of the parameter.

Real-time process control: A tough test

To test the Alsys system adequately, then, you'll want a program that closely approximates the jobs you expect the system to perform. The program used to conduct the test described in this article is an existing, nontrivial, tasking program that embodies many features you might want to verify. In particular, this program can verify multiple instantiations of a generic package with tasks (see example 14.8 in **Ref 1**); tasks with a family of entries; task types; and unconstrained discriminated records. The VAX, an IBM PC with an ANSI.SYS driver, and other ANSI terminals may require TEXT_IO PUT and TEXT_IO GET statements to string slices and overloaded PUT and GET calls that are part of a portable ANSI display; the test program verifies these features also.

To cover process-control applications, the program tests interactive I/O in tasking situations; formal arguments of a discriminated record type with default input values; some fixed-point math problems; types and subtypes with range constraints; overloaded enumeration literals; a software priority task working in both polling and interrupt-driven mode (see **Ref 1,** section 14.7); and nested exception handlers within a block (these handlers allow tasks to keep running or looping after an exception occurs). Because the test program

Selecting and interpreting Ada benchmarks

A simple lines-per-minute compilation-time count can be either very informative or very misleading. When comparing two different Ada compilers targeting the same computer and the same operating system, the lines-per-minute statistic is very accurate. The lines-per-minute count is less meaningful when you compare Ada compilers for different computers or different operating systems, and it becomes quite meaningless for interlanguage comparisons.

Lines per minute starts to lose meaning when you compare a 68000 to an 80286 compiler, for example, because the 80286 compiler must do more work generating code for the 64k-byte segmented memory of the 80286 machine. Comparing lines-per-minute compilation times for a 2000-line Turbo-Pascal program and for a 2000-line Ada program has almost no meaning. First, Turbo-Pascal produces small-memory-model programs with 64k-byte code and 64k-byte data segments. As a consequence, the compiler is not working as hard as an Ada compiler, which is generating code for a large-memory-model program.

Second, one line of Ada may represent hundreds of lines of code—especially when there are instantiations of generic packages. Aside from generic instantiations, Ada records are more powerful than Pascal records or C structures; one line of Ada record code therefore represents several lines of Pascal or C record code. Finally, when a large Turbo-Pascal program is broken into separate compilation units of non-ANSI Pascal, the compiler does not perform any interface type checking across units. An Ada compiler always performs type checking across separate compilation units.

Selecting run-time benchmarks

You have to consider at least three aspects of run-time benchmarks: comparisons of different Ada compilers running on the same machine; comparisons across different computers or host operating systems; and comparisons of Ada with other languages, such as Fortran, C, and Pascal.

The best set of Ada benchmarks for comparing one implementation of Ada with another is documented by Clapp et al **(Ref 2)**. That article presents a rigorous test suite for checking the time to call a procedure, both with and without arguments; for checking the time to reference static vs dynamic variables within a block; and for checking tasking, for which the test suite provides several benchmarks.

On the other hand, you'll find scant information on how non-tasking Ada compares with Fortran, C, or Pascal. Some tests carried out with DEC Ada have shown that DEC Ada is 30% faster than Fortran for Whetstones, 10% slower for matrix inversion, and 20% slower for database processing. These are unofficial tests, however; it's not known if the matrix-inversion algorithms were adjusted to compensate for column-row Fortran storage or row-column Ada, C, Pascal storage, or if static variables were used for both Fortran and Ada.

Make adjustments

When performing interlanguage benchmarks, you must adjust the algorithms to account for row-column or column-row storage conventions, to ensure that static or dynamic variables are used consistently, and to ensure that both languages allow for loop optimizations. For example, hard-wired Ada loop ranges for accessing all elements of a 10-element vector X—that is, "for I in 1 . . . 10"—will be much slower than "for I in X'FIRST . . . X'LAST." By ignoring built-in Ada attribute functions, you force Ada to check all subscripts at execution time. Use of the attribute functions allows for fast run-time operation, because the Ada compiler can perform all subscript checking during compilation. The upshot is that simple, line-by-line translations of benchmark programs will be very misleading.

In the *Ada Newsletter* (Vol IV, No 3, August, 1986), Virginia L Castor, director of the Ada Joint Program Office, laments the lack of a complete standard test suite to answer commonly asked benchmark questions. The Ada community should work on building a public-domain, readily obtainable test suite.

TABLE 1—ALSYS V1.2 COMPILE AND LINK BENCHMARKS USING CCCP

MODULE NAME/PC FILE NAME	SOURCE BYTES	SOURCE LINES	COMP TIME SEC	LINK TIME SEC
package GENERIC_RANDOM				
gran.ads—generic random numbers	168	3	15	
gran.adb—body	973	21	20	
package SENSOR_PACKAGE				
psen.ads—power, pressure, and temperature functions, and types kilo, atmospheres, degrees	774	11	31	
psen.adb—body; instantiates gran 3 times	4886	67	101	
package GLOBAL_TYPES_AND_DATA				
ptad.ads—types and data; contains many discriminated records	13,798	134	99	
ptad.adb—body; does any needed data/file initializations	8448	48	102	
package IO_FOR_CCCP_III				
pio.ads—instantiates TEXT_IO 9 times	881	16	543	
pio.adb—null body	194	3	28	
package DISPLAY_DISPLAY				
pdis3.ads—display driver spec; ANSI escape codes, and other display controls	5712	35	55	
pdis3.adb—body	17,920	145	275	
package PACKAGE_SENSOR_TASK				
st.ads—sensor task type spec	645	17	28	
st.adb—body: processes read, operator command, or log interrupts; one display line per sensor is updated	37,504	298	478	
package ALL_SENSOR_TASKS				
ast.ads—creates one power, pressure, and temperature task	592	14	41	
ast.adb—body: initializes each sensor task object declared in ast.ads	474	7	38	
package PRIORITY_INTERRUPT_CONTROLLER				
ppic.ads—the priority interrupt controller: whenever simultaneous interrupts occur, power, then pressure, then temperature will be serviced in priority order	836	17	30	
ppic.adb—body: can be implemented using either a polling or interrupt-driven design; PPIC can also detect when the system is sampling too fast by keeping track of the 'COUNT task que	11,520	88	191	
package GENERIC_PACKAGE_INTERRUPT_GENERATOR				
gigt.ads—generic interrupt generator task: a programmable timer that can be replaced with a FOR ENTRY use #hex representation clause to point at hardware timer/clocks	826	19	21	
gigt.adb—body	6016	53	50	
package ALL_INTERRUPT_GENERATORS				
aigt.ads—instantiates all interrupt generators for power, pressure, temperature, and logging	1459	24	220	
aigt.adb—null body	131	2	30	
package PACKAGE_OPERATOR				
pop.ads—an interactive operator input task that parses commands and dispatches commands; it also provides context-sensitive help when errors are made	654	19	40	
pop.adb—body	51,428	399	1002	
PACKAGE_OPERATOR.DISPCH				
dispch.adb—separate procedure: this does the dispatch of a valid command	43,039	317	330	
procedure CCCP_III				
cccp3.adm—CCCP_III main program for the CCCP	38,912	50	85	
BIND CCCP_III				180
SOURCE TOTALS	247,790 SOURCE BYTES	1807 SOURCE LINES	3853 SEC 64.2 MIN	180 SEC

LIBRARY TOTALS	
adalib (bytes)	319,488
macperm (bytes)	636,928
libprop (bytes)	104
OBJ FILE (bytes)	191,024
EXE FILE (bytes)	200,065
TOTAL PROGRAM (MEGABYTES)	1.339316

NOTES:

1. COMPILER USES 6M-BYTE DISK, 4M-BYTE RAM, AND NEEDS SCRATCH DISK SPACE OF 4M BYTES. ALL LISTINGS WERE TURNED OFF.
2. EXECUTION REQUIREMENTS: 344k-BYTE PC/AT WITH 80287 (8k-BYTE RUN-TIME DEFAULTS), 200k-BYTE EXE FILE.

To test the Alsys system adequately, you'll want a program that closely approximates the jobs you expect the system to perform.

was originally developed on a VAX VMS 4.4 system using DEC's Ada 1.2 or 1.3, it can also test the portability of tasking source code.

This Command and Control Computer Program (CCCP) monitors power, pressure, and temperature sensors at nominal sampling periods of 3, 2, and 2 sec, respectively. After taking the readings, the program compares each reading with an upper and a lower threshold. If a reading is out of bounds, or if the reading can't be taken (for example, because of an inactive sensor), the program displays and posts alarm indications. Inverse ANSI-terminal video attributes provide highlighting of selected fields in the display. If multiple tasks simultaneously request sensor readings, the program services power, pressure, and temperature, in that order of priority.

An interactive task allows an operator to enable and disable sensors, change thresholds, clear alarms, change sampling periods, and enable and disable logging for a specified number of hours. This operator task also provides context-sensitive help when commands are improperly entered. Nine tasks in all share the CPU **(Fig 1)**.

This 2000-line, sensor-monitoring program also allows you to take meaningful measurements of compilation time in lines per minute, tasking size and timing information, separate compilation features, and other vital statistics. Statistics can be misleading, however (see **box**, "Selecting and interpreting Ada benchmarks").

Checking compile, link, and run times

For the test described here, the Alsys compiler compiled the entire CCCP without error—including generics, tasking, generic packages containing tasks, and other advanced features. The compiler/linker then produced executable code. Several other mainframe Ada compilers couldn't compile this program at all.

Running on a 6-MHz PC/AT with its original hard-disk drive, the system takes approximately one hour to compile the program. Once the initial compilation is complete, however, it's easy to change the bodies of selected subsystems, because Ada allows you to store package interfaces and package bodies in separate files. **Table 1** shows the exact compile- and link-time information, by program unit. Because the IBM PC/AT does not accept file names longer than eight characters, both the Ada unit name and the corresponding IBM PC/AT file name are listed in the table. Here, file type *.ads denotes package specifications, *.adb denotes package bodies, and *.adm denotes main procedures.

Because many of the sample test's routines used generics, one would expect a much higher effective lines-per-minute value in the compilation benchmark. However, the generic pio.ads instantiated TEXT_IO nine times and therefore had a very long compile time, even though it was only 16 lines long.

You can vary the run-time options

The next question you'll want to ask is, will the executable code fit into available RAM? Alsys Ada offers several modes of operation; the most difficult mode squeezes the code sufficiently to allow it to run on the least capable IBM PC equipped with no more than 640k bytes of RAM.

To match a program to the available RAM space, Alsys run-time options let you vary the size of the stack for the main procedure (64k-byte default), for each task stack (8k-byte default), for the initial heap (64k-byte default); and for the heap increment (64k-byte default). It turns out that, on a PC with 512k bytes of RAM (457,584 bytes free if you include DOS overhead), you can safely run the CCCP by specifying 8k bytes for each stack and heap when the compiler prompts you for their sizes. Under these conditions, this 2000-line CCCP, which has no less than nine instantiations of TEXT_IO and four instantiations of the generic interrupt generator, needs only 344k bytes of RAM in which to run.

The size of the TEXT_IO package is an important consideration. Although it's commonly stated that embedded systems do their own I/O, TEXT_IO packages can be quite useful for formatting data into strings that can be sent out, one character at a time, via a low-level I/O call. A simple TEXT_IO benchmark shows a 36,113-byte overhead for TEXT_IO, a 608-byte additional overhead for INTEGER_IO, a 992-byte overhead for FLOAT_IO, a 1584-byte overhead for FIXED_IO, and a 1616-byte overhead for ENUMERATION_IO.

Alsys provides four compile options that affect execution performance: I_86 mode for operation on 8088/8086-based PCs; I_286 mode for the PC/AT (80286) running in real 8088/8086 mode; protected PC/AT mode (code in low memory and data above 1M byte); and extended PC/AT mode (heap, code, and data above 1M byte with stacks in the lower 640k bytes). Because the system clock's resolution, under PC-DOS, is no better than 1/18 sec, Alsys provides a bind/link option that provides access to the PC/AT's hardware timer, which has a resolution of 1/1024 sec. For systems that use

The compiler produces executable code that can switch tasks as fast as a MicroVAX.

TABLE 2—PIWG RENDEZVOUS BENCHMARK

COMPUTER	OPERATING SYSTEM	VENDOR, VERSION	RENDEZVOUS TIME (1000×20 ITERATIONS)
VAX-8650	VMS 4.4	DEC ADA 1.3	0.2 mSEC
VAX-11/785	VMS 4.4	DEC ADA 1.3	0.8 mSEC
MICROVAX II	VMS 4.4	DEC ADA 1.3	1.3 mSEC
IBM PC/AT			
6-MHz 80286	DOS 3.1	ALSYS ADA 1.2	3.3 mSEC
8-MHz 80286	DOS 3.1	ALSYS ADA 1.2	2.5 mSEC
IBM PC/XT			
4.77-MHz 8088	DOS 3.1	ALSYS ADA 1.2	8.7 mSEC
9.54-MHz 8086	DOS 3.1	ALSYS ADA 1.2	3.1 mSEC

NOTES:

1. PROGRAM VAX REND FROM THE VOLZ TEST SUITE, TESTED ON UNLOADED VAXs DURING THE MORNING HOURS.
2. BOTH THE DEC ADA 1.3 AND ALSYS ADA 1.2 SYSTEMS ARE INTENDED FOR DEVELOPMENT; CONSEQUENTLY, THEY MUST RUN ON TOP OF A NONREAL-TIME DOS. RUN-TIME PERFORMANCE CANNOT BE OPTIMIZED. ALSYS IS NOW COMMITTED TO UPGRADING ITS PC COMPILER INTO A SYSTEM THAT CAN PRODUCE CODE THAT IS EITHER EFFICIENT FOR EMBEDDED PCs OR ACCOMMODATING FOR HOST OPERATING SYSTEMS.
3. ALTHOUGH THE DEC 1.3 AND ALSYS ADA 1.2 SYSTEMS WERE INTENDED FOR DEVELOPMENT USE ONLY, THE RENDEZVOUS TIMES FOR THESE SYSTEMS ARE NOT UNREASONABLE. BECAUSE THE IBM PC FAMILY PROCESSORS HAVE A SIMILAR 64k-BYTE SEGMENTED ARCHITECTURE, AS DOES THE 1750A, THE ABOVE RESULTS ARE REPRESENTATIVE OF RENDEZVOUS TIMES OF CODE THAT CAN RUN ON TOP OF NONREAL-TIME 1750A HOST OPERATING SYSTEMS RUNNING AT AN EQUIVALENT PC CLOCK-SPEED. WHEN MATH LIBRARIES (SINE, COSINE, ETC) BECOME AVAILABLE FOR THE ALSYS PC ADA, YOU WILL BE ABLE TO CARRY OUT NUMBER-CRUNCHING BENCHMARKS SUCH AS FFT ROUTINES IN ADA, FORTRAN, AND C ON BOTH THE VAX AND PC.

polling (that is, an endless loop that checks for some event every *n* seconds), PC-DOS imposes a minimum polling period of 1/18 sec and gives unacceptable performance. On the other hand, you can usually convert a polling routine to an interrupt-driven service routine that is not limited by the PC-DOS timer's resolution.

When you're using the fast-timer option on the PC/AT, the polling version of the priority-interrupt-controller task works as well as the interrupt-driven version, and both versions keep pace with a MicroVAX. The interrupt-driven version works quite adequately on an IBM PC when you're using the DOS timer with 1/18-sec resolution.

Although the CCCP serves as an excellent test case for nontrivial compile, link, and execute functions, the sampling speeds on the VAX are limited by the time it takes to transfer one 80-column line of text to the screen over a serial link. Consequently, you should not use this program if you want to determine basic Ada run-time benchmarks, such as the rendezvous time. For run-time benchmarks, you should use the 1986 PIWG test suites (**Table 2**).

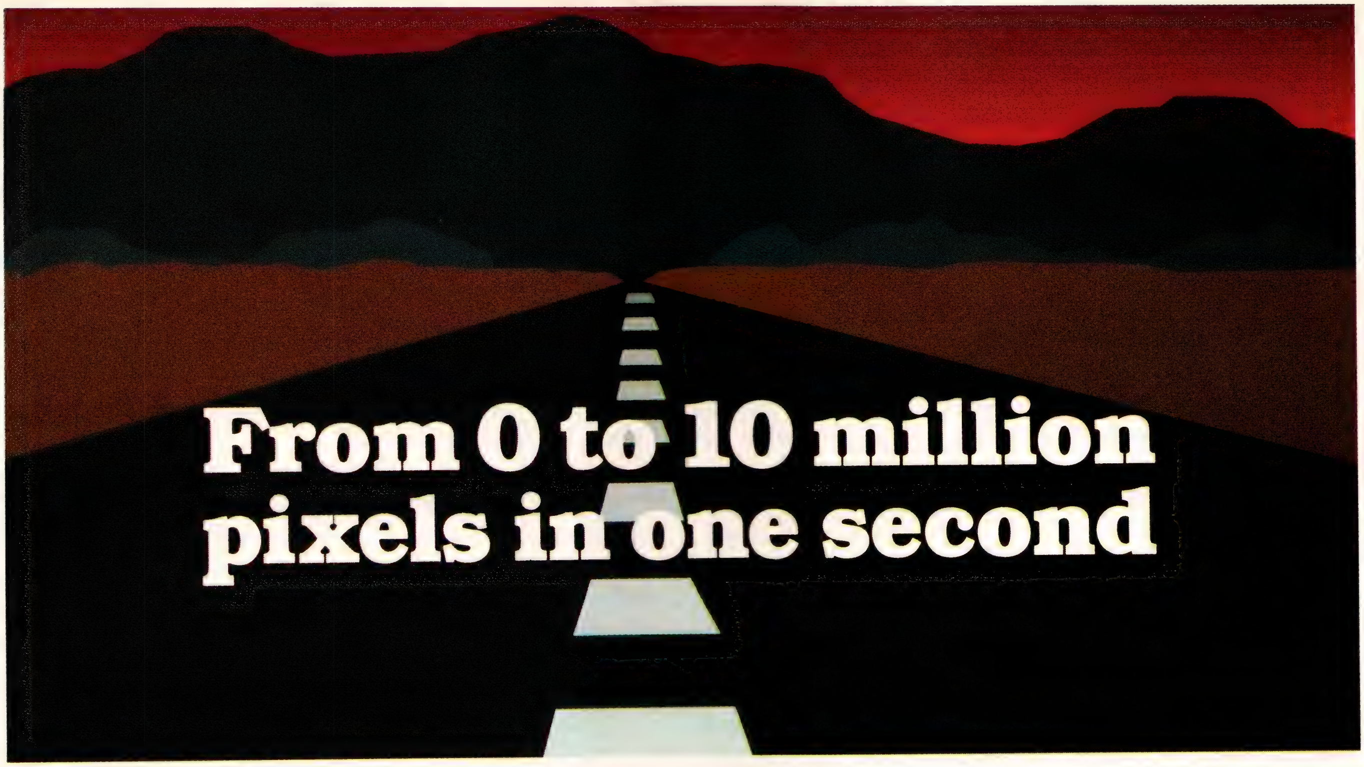
Setup, interface, documentation, support

Alsys guarantees operation of the compiler only with its I/O and memory board; in fact, it will only sell the compiler bundled with the board at this time. Consequently, setup consists of configuring the company's board as the first 4M bytes of memory, and any other memory board as an auxiliary RAM disk. If you can live with this restriction, the installation is straightforward.

The Alsys Ada-to-PC interface is well thought out and a pleasure to use. Alsys conveniently uses Ada-named notation (or positional notation) for passing parameters to the compiler, and the company has found a reasonable method of conforming to the PC's 8-character limit on file names without similarly restricting the names of the Ada modules. You can abbreviate all commands and parameters, provided the abbreviations are unique.

Overall, the documentation that comes with Alsys Ada 1.2 is first rate, although it's too alphabetical in organization. Alsys does provide three appendices for the first section—one for a sample session, one for a command summary, and one for filling out trouble reports. Unfortunately, there is no index, nor is there a list of all possible run-time error messages. All of the information you need is in the documents, but it's difficult to find quickly. The documentation should have at least an alphabetical index and a functional index. Alsys agrees, and it hopes to add indices in future releases.

Alsys should also provide an appendix on the development and running of large programs. Currently, this information is scattered about the manual. For example, to allow the sharing of code space, you should choose task types with initialization entries, in prefer-



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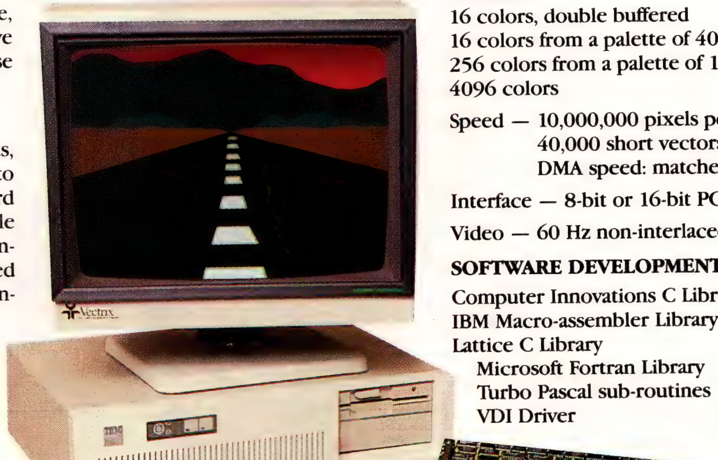

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The system provides four compile options that affect execution performance.

ence to generic packages that contain anonymous tasks. In addition, commands for unloading and loading the Ada compiler (RESIDENT switch on the SYSTEM command) let you free some of the available space for running a large program. This information could be collected in one appendix, and it would also be useful if such an appendix reviewed the advantages and disadvantages of using access variables, instead of variant records, to hold large, variable-dimensioned arrays.

The documentation of the developer's kit is equally impressive. Alsys includes two packages (DOS and DOSE), for accessing PC-DOS and BIOS functions. An extensive section tells you how to write your own assembler code; for simple type marks the interface is fixed, but for variant structures, Alsys reserves the right to make changes in future releases. Although the DOS and DOSE packages are extremely useful for getting at the hardware, Alsys should also support the ANSI Ada representation clauses and low-level constructs that would complete the Ada-to-machine interface. These features are especially important, because the DOS interfaces don't allow for true interrupt-driven operation. (Alsys plans to support these features in future releases.)

Telephone and update support has been very good. Alsys even provides a sample software trouble report (STR) on disk for reporting errors to the factory. The test conducted by this author revealed several bugs in the prerelease 1.0 compiler; Alsys quickly tracked the problems down so that version 1.2 was nearly perfect. In addition, the company discovered several obscure run-time system annoyances. For example, a drift in the run-time system clock counter caused the program to run 1.5 times slower than the commanded sampling rate. Also, a very subtle problem caused the program to crash after 10 hours of operation, with a FIND TABLE ERROR message; the problem was traced to an erroneous (but nonfatal) use of the terminate error, which caused the run-time system to raise an internal constraint-error. However, as long as you use the terminate alternative in such a way that its effect is well-defined, this bug will not affect program operation.

A survey of other Alsys users confirmed these findings about the company's support record. For example, Alsys was able to track down and work around conditions that were raising exceptions across package boundaries. In general, if you submit clear trouble reports, and if you simplify your program example, Alsys support is fast and efficient.

You should be aware of one minor user-interface bug. If you give a print-screen command when you are at the Ada prompt, the system locks up. To avoid this outcome, just give a system command before the print-screen command.

One can always hope for more

However good a product is, there's always room for improvement. Alsys could effect the following enhancements, and in many cases is working to that end, as indicated.

- Add representation clauses; the current method of gaining access to the machine requires polling and an assembler routine (scheduled for future release).
- Offer an optional math_lib that's compatible with the VAX math-lib (currently under test).
- Provide a pragma that sets the default INTEGER and FLOAT sizes.
- Change the default on the LIB_MANAGER.NEW command to "tasking=yes."
- Include a pragma or an alternate TEXT_IO library that allows for asynchronous I/O and does not halt other tasks while waiting for the final carriage control (the current way to accomplish this effect is to use the package DOS, DOS.READ_KBD_ . . . and poll the global variable KBD_DATA_AVAILABLE in a loop with a 0.1-sec delay to let other tasks in).
- Provide a pragma that allows for arrays larger than 64k bytes; unless you use pointers, arrays must fit within a 64k-byte segment (under investigation for future releases).
- Include time-slice options (under investigation).
- Include documentation on the run-time tasking scheduler (is it fair? is it round-robin? are tasks that are ready to be executed also ordered by the degree of staleness of the delays? etc).
- If possible, allow the DOS editing keys to work.
- Offer an optional debugger, and include a section in the manual on how best to debug programs (in development).
- Provide an 8087/80287 emulator library (for additional cost).
- Provide a timer stub that could be linked in to allow an IBM PC to access AST, Quadram, or Seattle memory-board timers (each uses a different I/O port).
- Include an appendix on developing large programs for best execution or minimum memory.

You can use the current version of the compiler and

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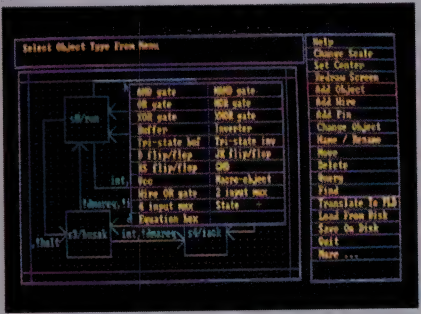

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system for the following applications: education, because the compiler can be trusted, and development, provided that you have an 8-MHz or faster machine, an extra RAM disk in addition to the Alsys 4M-byte RAM disk, and at least 20M bytes of disk space. When Alsys adds representation clauses, you will also be able to use the system for embedded PC applications. In release 1.3 of Alsys Ada, the rendezvous times will be eight times faster, interrupt-driven assembly language routines will be supported, and an optional source-code debugger will be available. Alsys also sells versions of Ada for 68000 systems.

For more information on Alsys Ada, you can contact the manufacturer at 1432 Main St, Waltham, MA 02154 (phone (617) 890-0030). The author can supply an executable version of the CCCP for the IBM PC, along with documentation, to readers who send a self-addressed, stamped envelope and a preformatted disk with their requests to the author at the Charles Stark Draper Laboratory, 555 Technology Square, MS 92, Cambridge, MA 02139. **EDN**

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Author's biography

Avram Tetewsky is a staff analyst at the Charles Stark Draper Laboratory, (Cambridge, MA), where he is responsible for modeling and for research in new signal-detection algorithms. Avram holds MS and EE degrees from the Massachusetts Institute of Technology. His hobbies include swimming and playing the piano and guitar.

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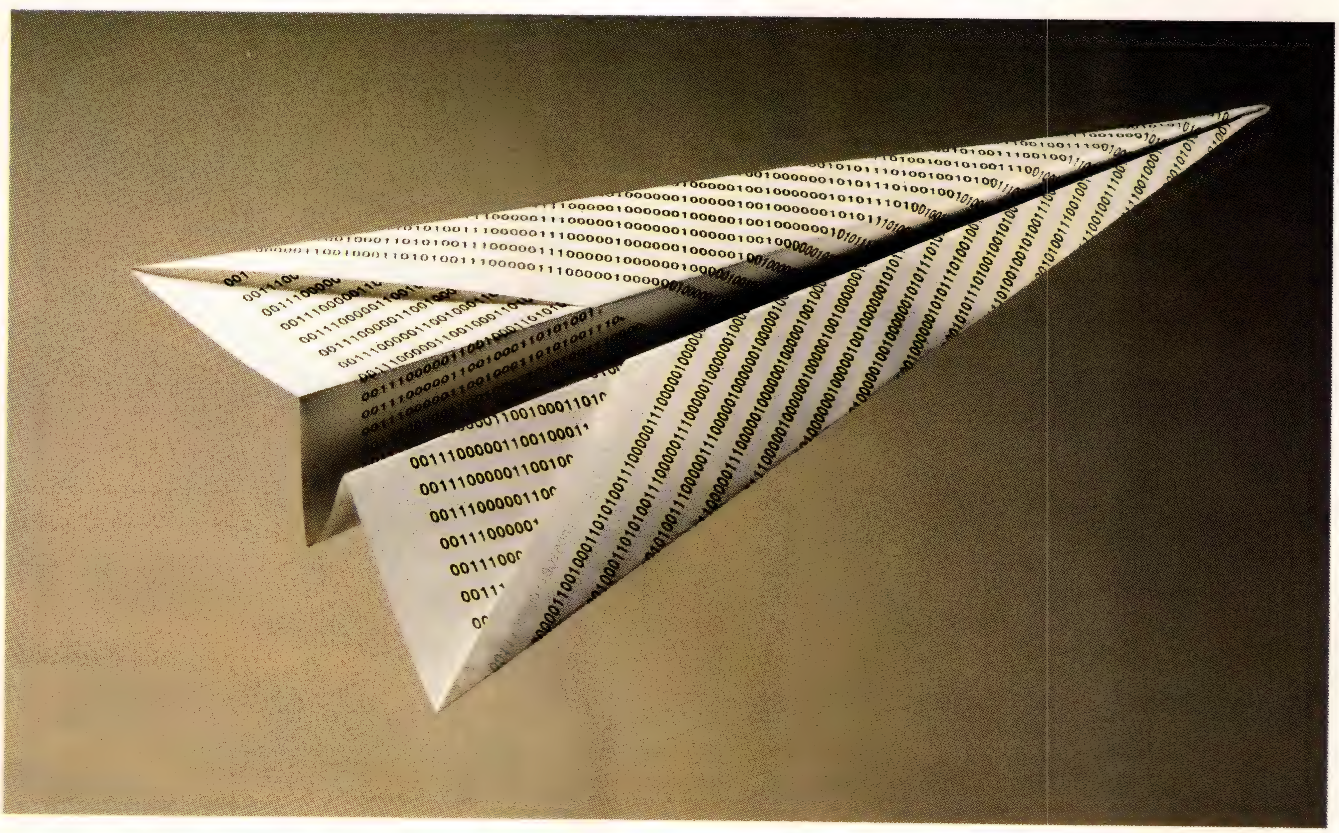

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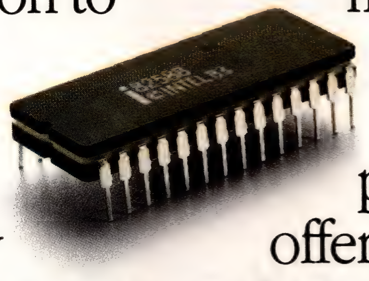

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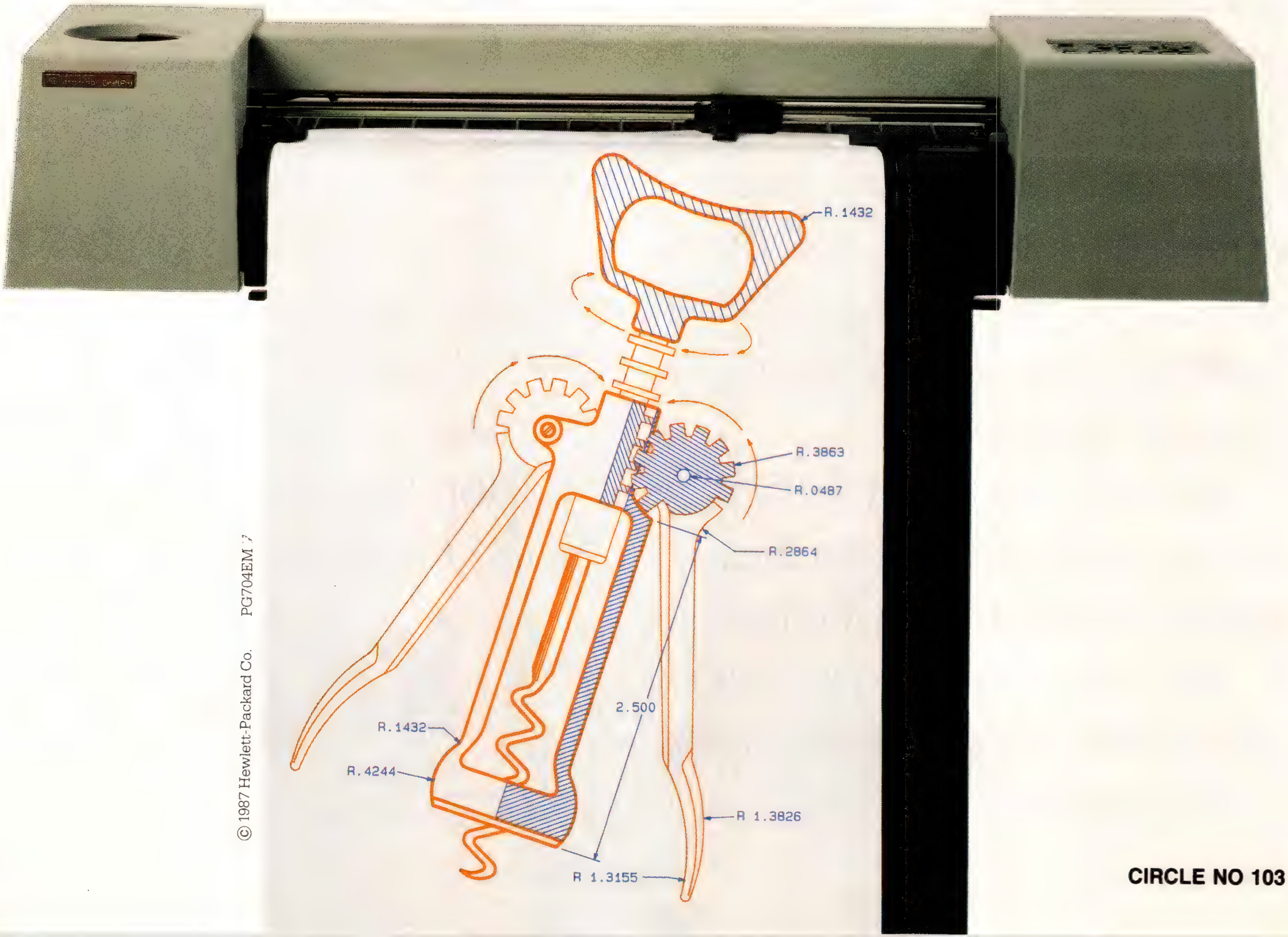

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CIRCLE NO 103

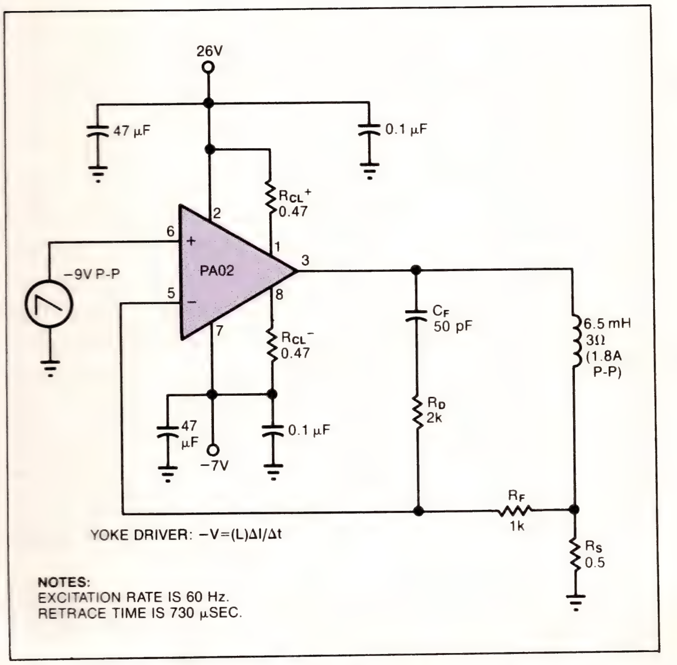
Power op amps solve deflection-yoke drive problems

Power op amps provide the ability to position beams in any desired position as well as the ability to retain a steady-state position. Putting both the power and signal stages in one compact package affords space/weight savings, and the lower parts count contributes to reliability.

Granger Scofield, *Apex Microtechnology Corp*

When compared with open-loop systems, closed-loop power op-amp circuits offer distinct advantages in current control for driving deflection yokes. By configuring a power op amp in a conventional voltage/current conversion circuit, you can use negative feedback to force the coil current to stay exactly proportional to the control voltage. The resulting higher accuracy makes many new applications, such as E-beam lithography, heads-up displays (which require random beam positioning), and other complex data displays, feasible.

By placing the nonlinear impedance of the deflection yoke inside the feedback loop of a power op amp, you can readily realize steady-state positioning, which is difficult, if not impossible, to achieve with open-loop circuits. In addition, using power op amps you can easily design sweep systems with substantially improved linearity. Finally, the op amps' versatility helps speed the design process and reduce development costs. The end result is a higher-accuracy display that uses fewer parts and has better reliability.



YOKE DRIVER: $-V=(L)\Delta I/\Delta t$

NOTES:
EXCITATION RATE IS 60 Hz.
RETRACE TIME IS 730 µSEC.

Fig 1—Specifically designed to drive an RCA Cody II tube, *this circuit provides high accuracy, a high slew rate, a fast settling time, low crossover distortion, and low internal losses.*

The vertical-deflection circuit of **Fig 1** is specifically designed to drive a high-efficiency RCA Cody II tube.

Closed-loop power op-amp circuits offer distinct advantages in current control when driving deflection yokes.

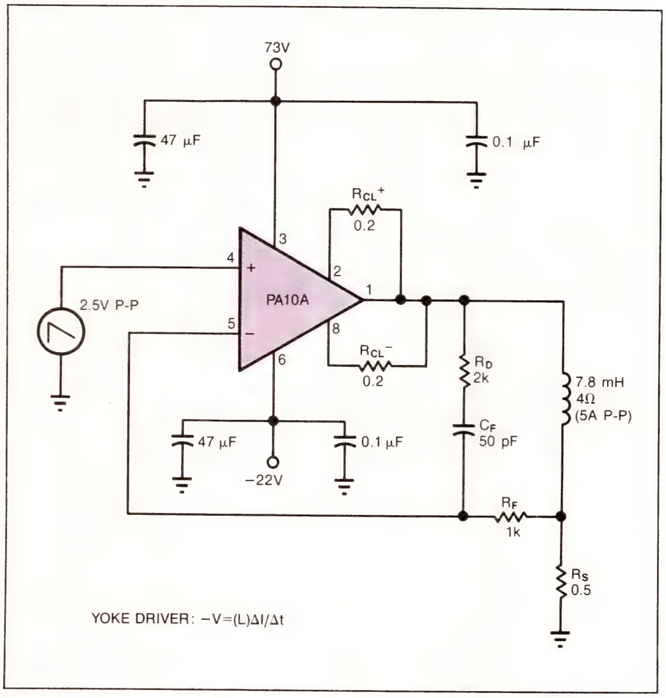


Fig 2—By using the PA10A power op amp *in place of* ***Fig 1'****s PA02, you can drive a 7.8-mH/4Ω coil at 5A p-p without changing timing requirements.*

The PA02 is well-suited to this application: It has very good linearity, a high slew rate, a fast settling time, low crossover distortion, and low internal losses—characteristics that are critical for a high-resolution display.

Sense resistor R_S, which converts the yoke current to a voltage for op-amp feedback, is the key component in this circuit. With the feedback applied to the inverting input, and the position-control voltage applied to the noninverting input, the summing junction's virtual-ground characteristic ensures that the voltage across R_S is equal to the input voltage. As a result, the highly linear control of the voltage across R_S ensures accurate beam positioning.

The value of R_S has a significant impact on the performance of this circuit. All op-amp errors—voltage offset, imperfect common-mode rejection, offset drift, etc—will appear across the sense resistor. To minimize these errors when they're translated into current, you must set the value of R_S as high as possible. If you choose a very large value for R_S, you can, in fact, reduce these errors to the point where they are insignificant. Unfortunately, choosing a large value for R_S will diminish drive capability and increase circuit power dissipation because the total coil current flows through the sense resistor.

To optimize the value of R_S for a given application, you must make some error-vs-efficiency tradeoffs, and so the inductance, transition times, and current level will define the necessary voltage drive requirements. The Cody II display is designed to operate at 50 or 60 Hz, with retrace times of 730 µsec and coil currents of 2.25A p-p.

To change the current in an inductor, the drive voltage (V_{DRIVE}) is proportional to both current change and inductance, but inversely proportional to transition time:

$$V_{DRIVE}=L\,di/dt$$
$$V_{DRIVE}=(6.5\text{ mH})(2.25\text{A}/15\text{ mSEC})\qquad\text{sweep}$$
$$V_{DRIVE}=(6.5\text{ mH})(2.25\text{A}/730\ \mu\text{SEC})\qquad\text{retrace.}$$

To determine the required supply-voltage levels, add the supply-to-output differential rating of the power op amp (listed on the data sheet) and the voltage dropped across the combined values of the sense resistor plus the coil resistance to these drive requirements:

$$V_{DROP}=I_P\,(R_S+R_L)$$
$$V_{DROP}=1.125\text{A}(0.5+3)=3.94\text{V}$$
$$V_S=V_{DRIVE}+V_{S-O}+V_{DROP}$$
$$V_S=0.98+2+3.94=6.92\text{V}\qquad\text{sweep}$$
$$V_S=20.03+2+3.94=25.97\text{V}\qquad\text{retrace.}$$

You must exercise some caution when you use nonsymmetrical power supplies because, under abnormal conditions, the inductive load has the potential to store energy from the higher-valued supply. For example, if the high-output voltage remains on the yoke longer than the normal retrace time, the collapsing magnetic field will discharge the stored energy into the lower voltage supply via the power op amp's inductive-kickback protection diodes. This collapse will generate a voltage transient on the supply rail; the transient's amplitude will be a function of the stored energy and the transient impedance of the power supply. If the transient- and supply-voltage combination exceeds the rail-to-rail voltage rating of the amplifier, you'll destroy the amplifier. A zener clamp on the amplifier output will minimize the possibility of this problem occurring.

Delve into stability concerns

Because the current-control capabilities of this circuit rely on feedback from the current/voltage-conversion sense resistor, the inductance of the yoke will introduce some phase shift into the feedback signal. Although the phase shift on a perfect inductor theoretically approaches 90°, the phase margin of an op amp is always less than 90°, so you must add some circuitry to prevent oscillation.

In **Fig 1**, the network consisting of R_D, R_F, and C_F shifts the feedback from current mode (via R_S) to direct-voltage mode at the higher frequencies. This scheme bypasses the extra phase shift introduced by the inductor. As far as component values for this network are concerned, first of all R_F must be much larger than R_S but must not be greater than 1 kΩ because the op amp's input capacitance would otherwise add phase shift. You then select R_D to properly dampen the circuit at the unity-gain frequency. R_D's value is usually a multiple of R_F; a safe starting value is $2R_F$. Finally, select C_F to establish the 3-dB corner frequency at one-third the unity-gain bandwidth of the amplifier. For the PA02's 4.5-MHz bandwidth, C_F should be 50 pF.

To develop an even more powerful deflection circuit, substitute the PA10A power op amp **(Fig 2)**. With this op amp, you can drive a 7.8-mH/4Ω coil at 5A p-p without changing timing requirements. Calculations for this design are

$$V_{DRIVE}=(5A)(7.8\ mH/15\ mSEC)=2.6V \quad \text{sweep} \quad (1)$$
$$V_{DRIVE}=(5A)(7.8\ mH/730\ \mu SEC)=53.43V \quad \text{retrace} \quad (2)$$
$$V_{DROP}=(2.5A)(0.5+40)=11.25V \quad (3)$$
$$V_S=2.6V+8V+11.25V=21.85V \quad \text{sweep}$$
$$V_S=53.43V+8V+11.25V=72.68V \quad \text{retrace.}$$

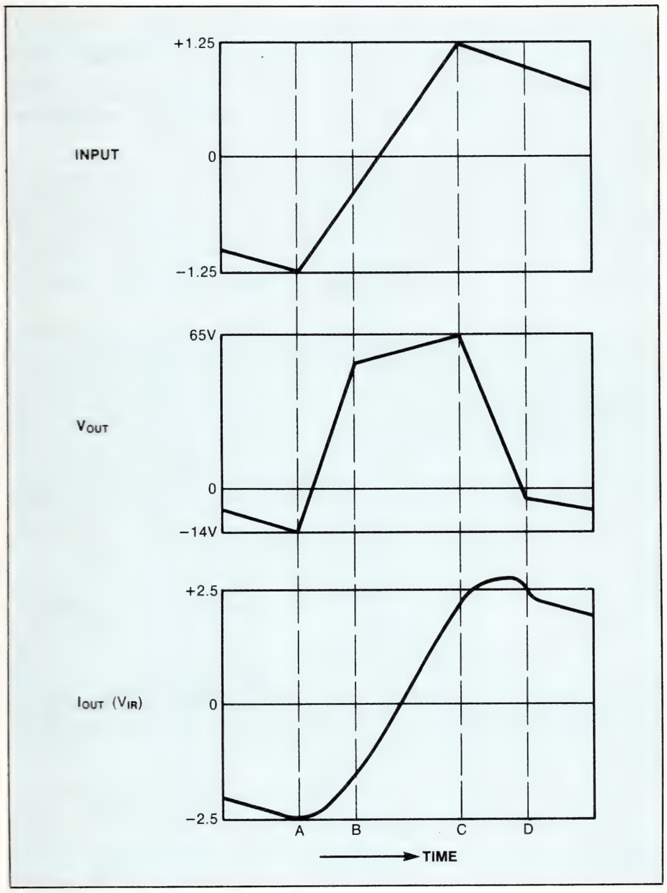


Fig 3—The op amp must generate these output voltage waveforms *to develop the desired retrace current step for the circuit of* ***Fig 2.*** *The trace preceding point A is the end of the sweep waveform.*

The circuits of **Fig 1** and **Fig 2** each have a 730-μsec retrace-time requirement. In both cases, the op amps easily meet this requirement because they have slew rates and settling times that are significantly faster than the retrace time.

To better understand the deflection application (as well as other applications), refer to **Fig 3.** You can see the output voltage waveforms the op amp must generate to develop the desired retrace current step for **Fig 2.** The trace preceding point A is the end of the sweep waveform and has a relatively slow current rate of change. The peak output voltage at point A equals the sum of **Eq 1** and **Eq 3.**

Retracing begins at time A, where **Eq 2** dictates the drive voltage required to achieve the retrace di/dt. From time A to time B, the amplifier is running at its slew-rate limit. The current in the yoke starts to track the input voltages at time B. From time B to time C, the op amp's output voltage is the sum of **Eq 2** and the value of instantaneous IR drops. **Eq 3** indicates the final value.

The abrupt slope change of the input waveform at point C again puts the amplifier in a slew-rate-limit mode until the output current is proportional to the input voltage (**Eq 1** plus IR drops). At point D, **Eq 1** is satisfied, and the amplifier will maintain the required current for the sweep portion of the waveform.

Fig 3 uses time expansion, which better illustrates the slew-rate and voltage-swing requirements for the amplifier. During the retrace section of the waveform, the amplifier has to sum the drive voltage (**Eq 1** and **Eq** 2) twice. In the **Fig 2** circuit, this drive voltage amounts to 112V. With the PA10A's typical slew rate of 5V/μsec, the slew time is only 22.5 μsec—an insignificant portion of the total retrace time. Once you understand the voltage-swing requirements, however, it's easy to see that slew rate becomes important as the scan rates increase.

Once you understand voltage-swing requirements, it's obvious that slew rate becomes important as scan rates increase.

In both **Fig 1** and **Fig 2,** having the nonlinear inductive element inside the op-amp feedback loop improves accuracy levels. In addition, the op amp's high gain and the use of negative feedback improves linearity.

Heads-up displays require swift transitions between any two points on the screen. The waveforms in **Fig 4a** illustrate the yoke's input-drive-voltage and current requirements for achieving a single full-scale step in beam position for **Fig 4b**'s circuit. The 3V levels sustain the steady-state current through the coil resistance and sense resistors; the 29V level corresponds to the peak output voltage required for a position change.

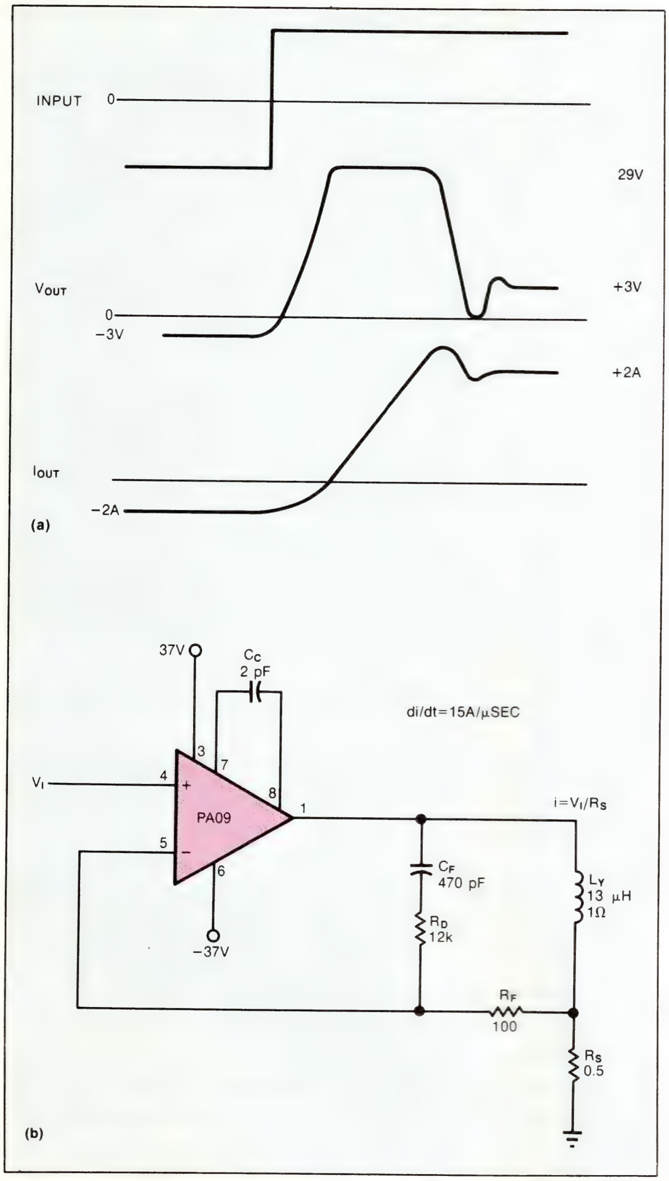


Fig 4—Heads-up displays demand swift transitions *between any two points on the screen. The waveforms in* **a** *illustrate what the circuit in* **b** *must generate to satisfy the yoke's input-voltage and current-drive requirements.*

You can use slew-rate and settling-time figures from the amplifier's data sheet to determine what percentage of the total transition time will be required for slewing and settling. As a starting point, it's reasonable to allow 50% of the total transition time.

The circuit in **Fig 4b** is designed to make a maximum transition in 4 μsec when delivering 2A to the 13-μH coil. Although the fundamentals of **Fig 4b**'s circuit are identical to those of the previous two circuit examples, the high speed involved does introduce some differences. To achieve rapid transitions, you must optimize amplifier slew rates, something you can accomplish quite easily with the PA09, a video power op amp with external phase compensation. Nonetheless, you'll have to examine the poles and zeros in the feedback loop because reactive feedback elements force the amplifier to operate over a very wide gain range—very high gain during transitions, but unity gain at steady state.

The network of C_F, R_D, and R_F sets high-frequency gain at approximately 100. At this gain, you can phase-compensate the amplifier and still maintain fast slew rates. Next, you must plot the feedback zero of the yoke-inductance and sense-resistor combination (**Fig 5a**). Then, you draw in the high-frequency feedback level of the RC network (which is approximately 40 dB) and select C_F to produce a pole approximately one decade below the intersection point. **Fig 5b** shows the PA09's open-loop Bode plot as well as modifications due to feedback effects—that is, a slope increase below 500 kHz and a shallow slope at the unity-gain crossing point to ensure stability.

With 50% of the total transition time set aside for slewing and settling, 2 μsec remains to change the yoke current with full voltage applied to the coil. You can calculate voltage requirements as follows:

$$\begin{aligned} V &= L\ di/dt \\ V &= (13\ \mu\text{H})(4\text{A}/2\ \mu\text{SEC}) = 26\text{V} \\ V_{\text{DROP}} &= (2\text{A})(0.5+1) = 3\text{V} \\ V_{\text{DRIVE}} &= 26\text{V}+3\text{V} = 29\text{V} \\ V_S &= 29\text{V}+8\text{V} = 37\text{V}. \end{aligned}$$

You also have to calculate the value of the phase-compensation capacitor per the requirements of the PA09. The amplifier's data sheet recommends component values as a function of circuit gain (R_D/R_F). With

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In the video frequency range, even a few inches of wire can raise the interconnection impedance and limit the output slew rate.

the recommended compensation capacitor, the PA09's data sheet indicates that amplifier slew rate will be 400V/μsec. For a 58V swing, this slew rate equates to a voltage slewing time of 145 nsec. Adding the settling time (1.2 μsec to 0.01%), the total is comfortably below the 50% allotment of 2 μsec.

Of course, you can modify component values during circuit testing to improve performance. In this particular case, the value of R_D had a considerable effect on circuit damping, which is predictable because R_D affects the corner frequency where the roll-off slope flattens near the unity-gain point. The value of C_F, on the other hand, wasn't particularly critical. Nevertheless, a 2-pF compensation capacitor, as opposed to the 5-pF value recommended on the data sheet, helped increase the slew rate without significantly affecting stability.

Some circuit-layout tips will help

Because of the PA09's high speed, you must take certain precautions to avoid any degradation in circuit stability and accuracy. To help prevent unwanted feedback, for example, use single-point grounding for the entire network or use a solid ground plane.

To ensure adequate decoupling at high frequencies, bypass each power supply with a tantalum capacitor of at least 10 μF and parallel it with a 0.47-μF ceramic capacitor. You should connect the ceramic capacitors directly between each of the two amplifier supply pins and the ground plane, and you should locate the tantalum capacitors as close to the amplifier as possible.

Use short input leads to minimize trace capacitance at the input pins. Input impedance of 500Ω max, combined with the PA09's input capacitance of approximately 6 pF, will maintain low phase shift and promote stability and accuracy.

You should also keep the output leads as short as possible. In the video frequency range, even a few inches of wire can have significant inductance, which will raise the interconnection impedance and limit the output slew rate. In addition, the skin effect increases the resistance of heavy-gauge wires at high frequencies. To minimize losses, it's best to use multistrand Litz wire to carry large video currents.

Finally, you must connect the amplifier case to an ac ground (signal common) even though it's isolated. In the video frequency range, the case can act as an antenna and cause errors or even oscillation.

The circuit in **Fig 6** drives the deflection yoke of a precision X-Y display from a ±15V supply. This transimpedance bridge is the only configuration that can provide the necessary high voltage drive from such supply levels. The circuit allows you to double the

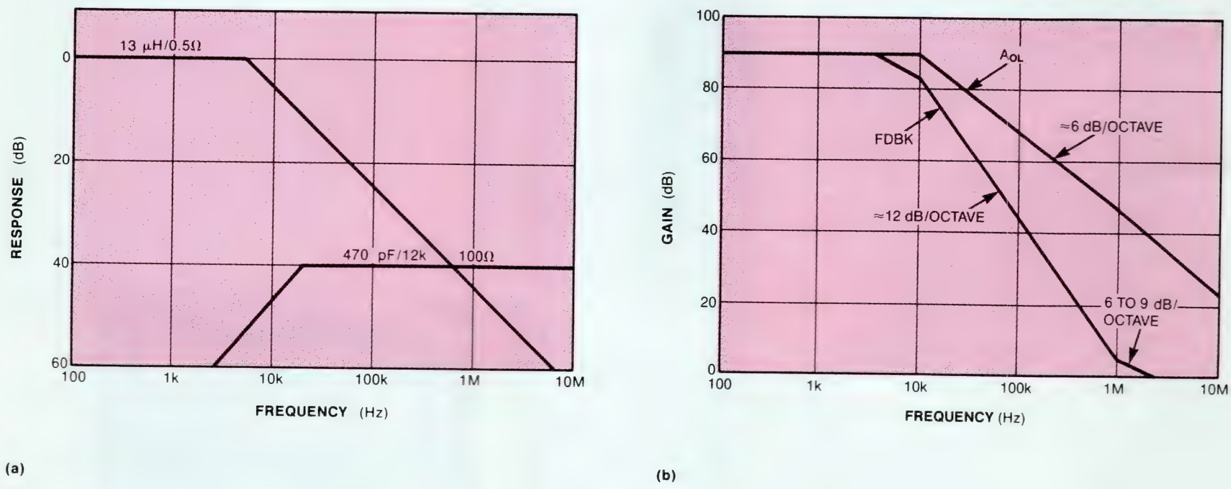

***Fig 5—You must examine the poles and zeroes in the feedback loop** closely to achieve rapid transitions. First plot the feedback zero of the yoke inductance and sense resistor, and then draw in the high-frequency feedback level of the RC network **(a)**. A look at the PA09's open-loop Bode plot **(b)** shows the modifications due to feedback effects.*

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CIRCLE NO 6

With a transimpedance-bridge configuration, you don't have to use separate supplies for CRT deflection.

amplifier's rated output voltage capability and thus eliminate the need to use separate power supplies for CRT deflection.

In **Fig 6,** sense resistor R_8 combines with IC_1 to implement a differential voltage-controlled current source. IC_2 functions as an inverter to provide an equal, opposite-phase voltage drive to the load. The feedback path of R_{1A} through R_{1D} performs the single-ended-to-differential conversion by making the output voltage a common-mode signal for IC_1. In this manner, the amplifier's common-mode rejection and the resistive-divider ratios maintain the transimpedance function (differential feedback from R_8 only).

Because R_{1A}/R_{1B} and R_{1C}/R_{1D} must divide the output voltage equally for both amplifier inputs, you'll have to use a matched or precision resistor network. In addition to initial matching, the network's temperature-tracking ratios are also critical. The series RC network, in parallel with the inductive load, reduces the load's phase shift at high frequencies and effectively eliminates the possibility of oscillation.

For a display with a 0.3-mH yoke inductance, a ±3.75A full-scale current requirement, and 0.4Ω dc coil resistance, the maximum transition time between any two points is 100 μsec. The calculations similar to those required for the previous examples are

$$V = L di/dt$$

$$V = (3\text{ mH})(7.5\text{A}/100\ \mu\text{SEC}) = 22.5\text{V}$$

$$V_{DROP} = 3.75\text{A}(0.5+0.4) = 3.375\text{V}$$

$$V_{DRIVE} = 22.5\text{V} + 3.375\text{V} = 25.875\text{V}.$$

Each amplifier in the bridge provides one-half the required drive level: approximately 13V. The PA02 is well-suited to this application because of its high 20V/μsec slew rate and its ability to drive the load close to the supply rail. During the beam transition time, the average output voltage swing of the circuit will be greater than 26V.

Because of the inductive load, the current flow will change direction only after the transition is 50% complete. This restriction allows both amplifiers to swing to their no-load saturation levels (less than 1V from the supply rail) for this time period. In addition, IR drops during this time period generate voltages that add to the amplifier drive. During the second half of the transition, the current direction changes and the amplifier output swing decreases. Even at 75% completion, however, each amplifier will still swing in excess of 13V because the current magnitude hasn't reached the 2A level.

EDN

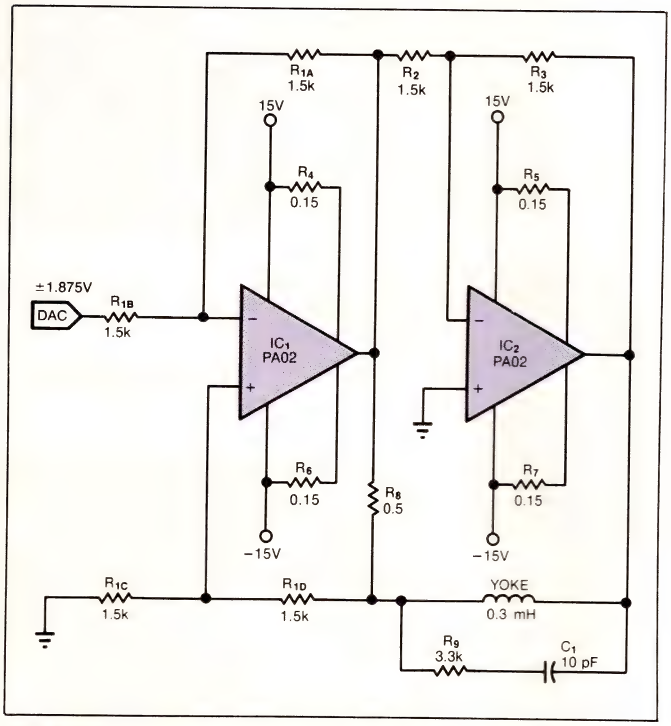

Fig 6—The transimpedance bridge is the only configuration *that can satisfy a deflection yoke's high-voltage drive requirements from a ±15V supply.*

Author's biography

Granger Scofield is vice president of marketing at Apex Microtechnology Corp (Tucson, AZ). In addition to product planning and seminar presentations, he provides technical assistance via an applications hot line and generates application notes and data sheets. Granger spends his leisure time riding motorcycles (on and off road) and tinkering with model trains.

Article Interest Quotient (Circle One)
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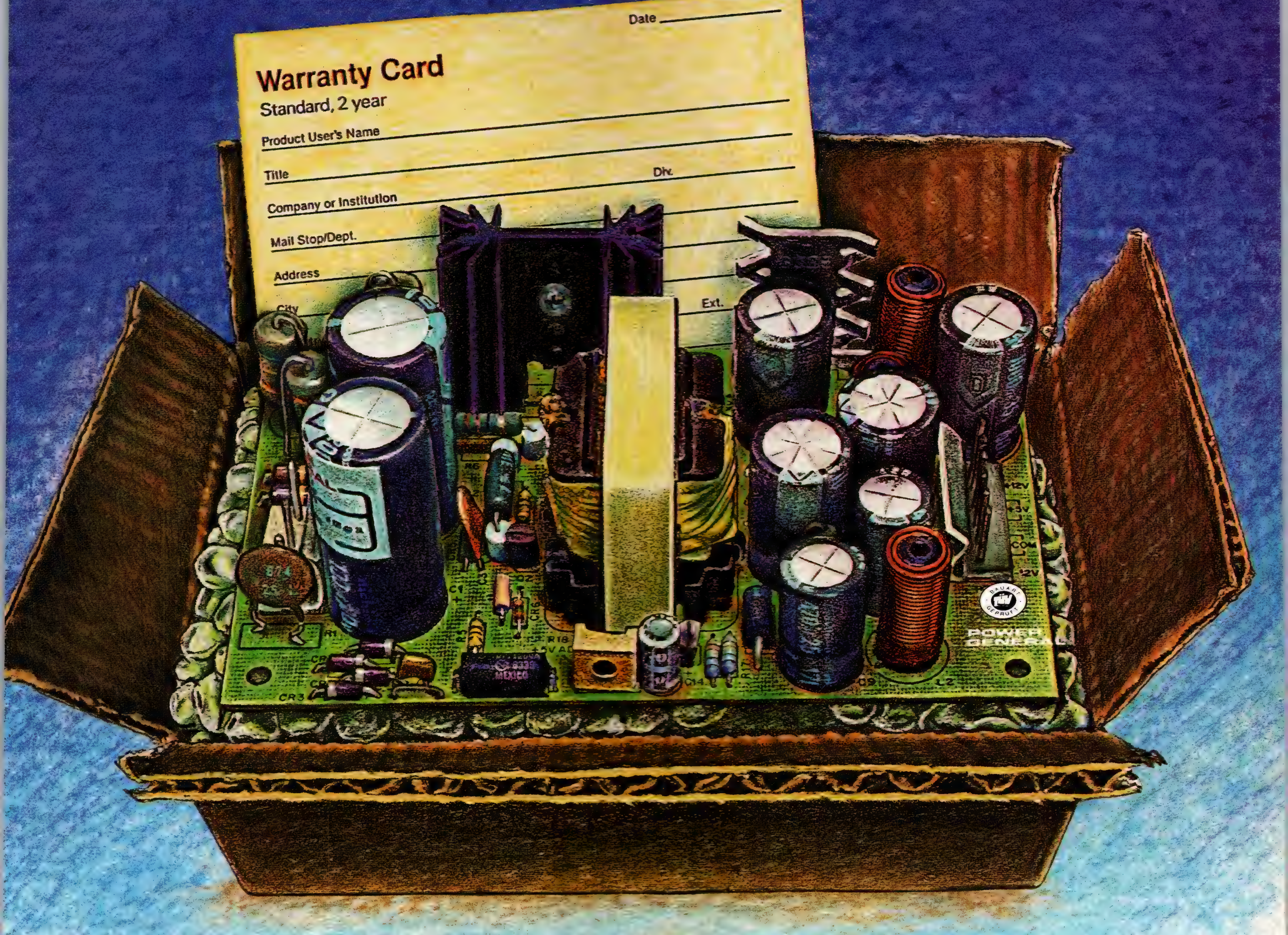

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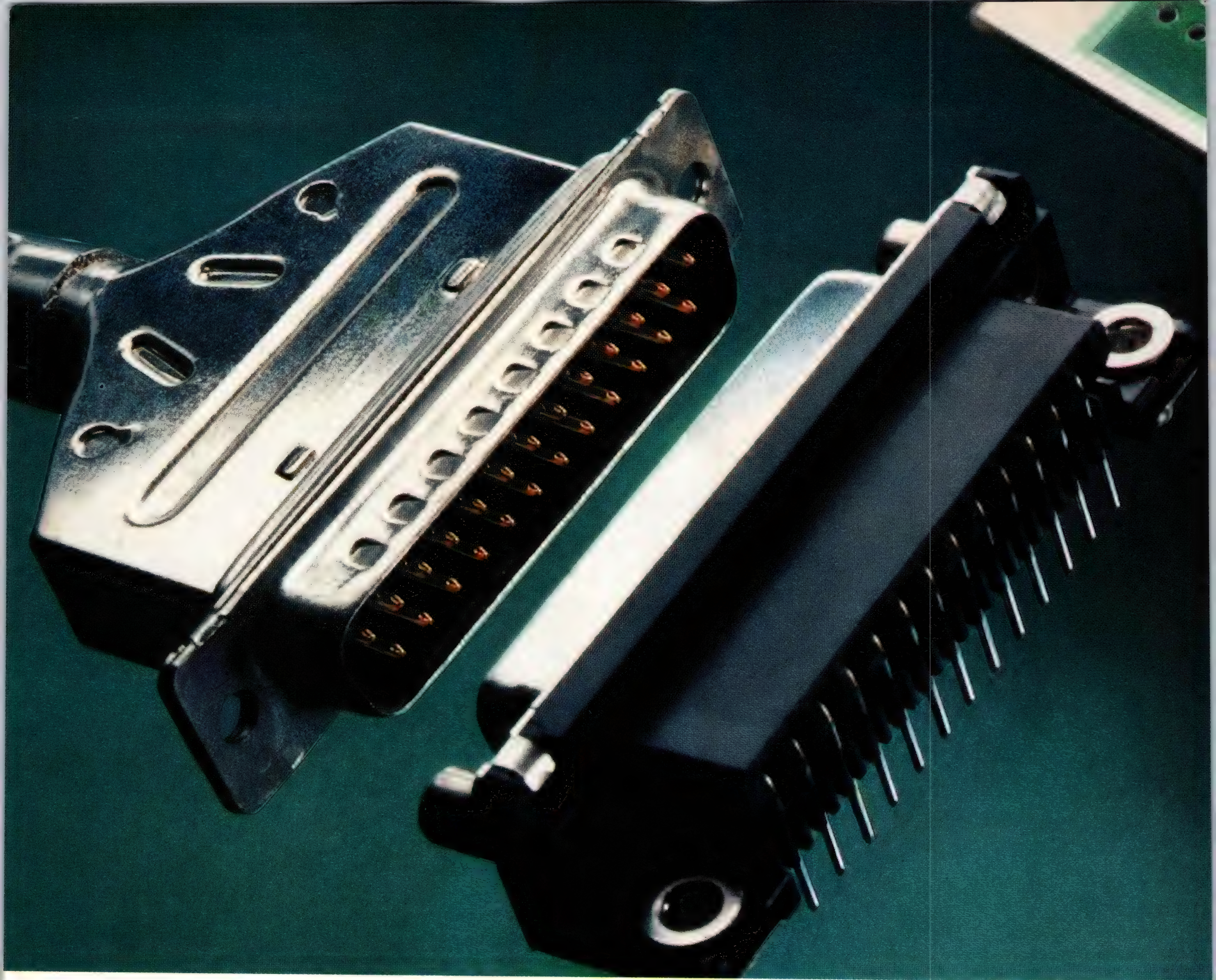
CIRCLE NO 143



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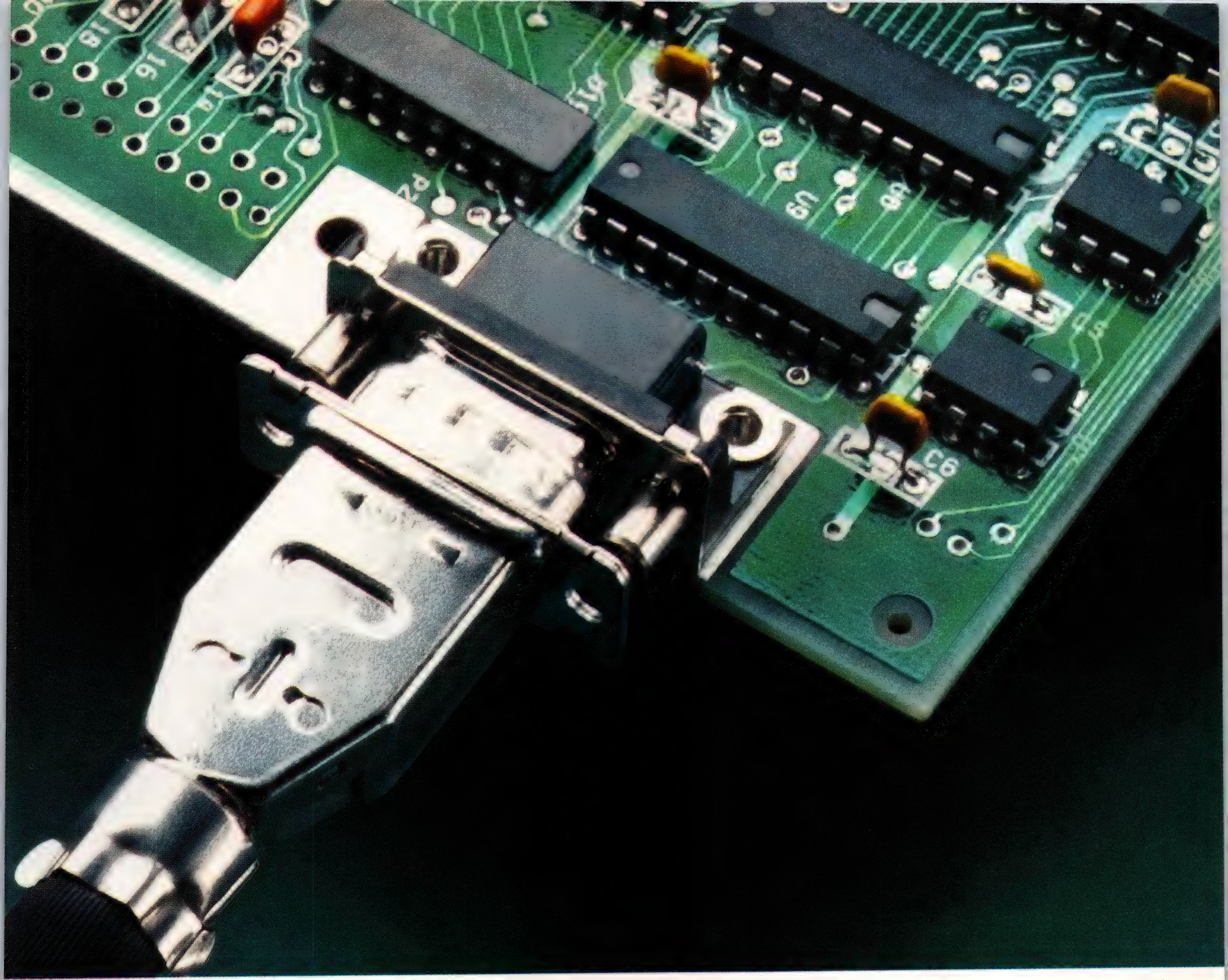

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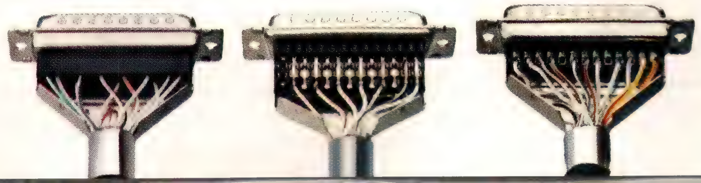

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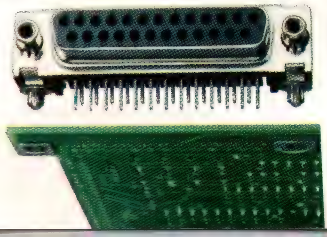

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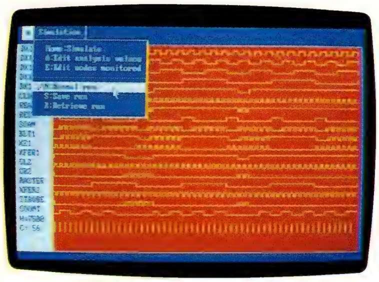

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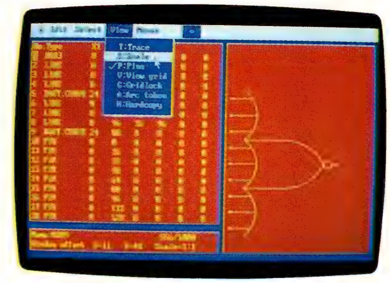

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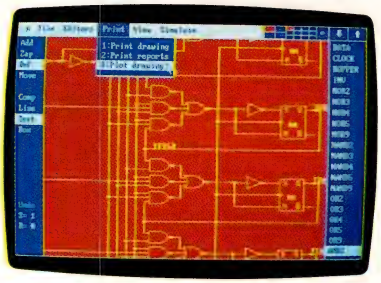

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CIRCLE NO 108

Designer's Guide to EDIF—Part 3

Use EDIF to create test vectors and verify your logic

This third installment of a 4-part series shows how you can transmit your CAE/CAD tests to any system that understands the Electronic Design Interchange Format (EDIF) by translating your test patterns into that format. After you have simulated an ASIC on a workstation, for example, you can have your foundry verify your test with the foundry's own, more precise, device models.

Esther Marx, Hart Switzer, and Mike Waters,
Motorola Inc

To transmit test patterns from a CAE system to a tester or to another CAE system, you must translate the data from the originating system's format to the receiving system's format. Today, you no longer have to write multiple translation programs to communicate with multiple CAE systems or testers. By using the Electronic Design Interchange Format (EDIF), a public-domain data format that presents and orders CAE/CAD information, you can make one translation and transfer your data to all the systems that accept EDIF.

A number of CAE vendors have added EDIF compatibility to their systems, and you can share EDIF data among any of these systems. Developing an EDIF translator isn't hard, but—as noted in earlier articles in this series—you must understand the syntax of EDIF (see those earlier articles, **Refs 1** and **2,** for an introduction to that syntax).

An EDIF test-pattern file begins with the line

```
(EDIF . . .
  (DESIGN X3700 (QUALIFY LIBRARY_100 CELL_4022))
  (LIBRARY LIBRARY_100 . . .
      (TECHNOLOGY . . .
      )
      (CELL CELL_4022 . . .
        (VIEW BEHAVIOR . . . .
          (INTERFACE . . .
) ) ) ) ).
```

In this statement, X3700 is the name of the design, LIBRARY_100 is the name of the library in which the design resides, and CELL_4022 is the cell within the library that contains the details of the design.

The library and cell descriptions are part of the design section of an EDIF file. You can add test patterns to any cell in a library. The port names and waveform descriptions required in the specification of your test patterns are part of the interface section in the library's cells.

Logic states are part of the "technology" section of

You don't have to write multiple translation programs to communicate with multiple CAE systems or testers; you only need an interface to EDIF.

the library. You use the "simulationinfo" statement to specify these logic states. The syntax of the simulationinfo statement is

```
(SIMULATIONINFO SIMULATIONINFONAMEDEF SIMULATIONVALUE
                                ARBITRATE ISOLATED [RENAME]).
```

"Simulationinfonamedef" stands in the place to be occupied by the name that you specify in your design statement; it can be any name you choose. You must use this name again when you create the "simulate" section.

In the place of "simulationvalue," you declare the names that you are using for the logic states in your test patterns. For example, you can write

```
(SIMULATIONVALUE FU FL FH RU RL RH DU DL DH).
```

You can use any name in your simulationvalue list. Typical states are unknown (U), high (H), low (L), high-impedance (Z), forcing (F), and resistive (R). Because other statements, such as "pairwise" and "logicwaveform," use the names that you define in the simulationvalue section, you should use abbreviated names.

You can avoid signal contention in a simulation by using "arbitrate" statements. An arbitrate statement specifies the outcome when logic states of unequal strength collide. The order of the logic states in an arbitrate statement corresponds to the order of the logic states in a simulationvalue statement. A pairwise list in an arbitrate statement contains the results of wiring a state to itself and to those states, referred to in the simulationvalue statement, that follow that state. For example, if you use a design that obeys the logic table

	H	L	Z	U
H	H	L	Z	U
L	L	L	Z	U
Z	Z	Z	Z	U
U	U	U	U	U,

you can create an arbitrate statement by copying the upper-right triangular matrix in row order. The "arbitrate" statement then becomes

```
(ARBITRATE (PAIRWISE H L Z U   L Z U   Z U   U)).
```

An "isolated" statement contains a single simulation value. This value is the state that you assign to unused input ports and to any net that includes no sources.

In addition to a simulationinfo section, the technology block must include a "numberdefinition" statement. In this statement, you specify the time units that you are using. The syntax of a "numberdefinition" statement is

```
(NUMBERDEFINITION NUMBERDEFINITIONNAME (SCALE)).
```

A library can contain only one numberdefinition statement. You may not write any time-dependent statements in your library until you have specified the time units. If you are using nanoseconds for your time units, the numberdefinition statement is

```
(NUMBERDEFINITION SI
   (SCALE TIME 1 (E 1  - 9))).
```

By combining the simulationinfo and numberdefinition statements, you can create a complete technology block, annotated with comments explaining the choice of abbreviations:

```
(TECHNOLOGY X3700
  (SIMULATIONINFO X3700
    (SIMULATIONVALUE H L Z U)
    (ARBITRATE
      (PAIRWISE H L Z U   L Z U   Z U   Z))
    (ISOLATED Z)
  )
  (COMMENT "H = HIGH, L = LOW, Z = HIGH IMPEDANCE,
            U = UNKNOWN")
  (NUMBERDEFINITION SI
    (SCALE TIME 1 (E 1  - 9))
  )
  (COMMENT "EDIF TIME UNIT IS NANOSECONDS")
) (COMMENT "END TECHNOLOGY").
```

Test patterns verify functional behavior

Once you have completed your technology block, you can describe the input and output ports of your cells. The description of cell ports is a part of the "define" statement. The define statement is a part of the interface section in the behavior view of a cell. The syntax of a define statement is

```
(DEFINE DIRECTION DECLARETYPE DECLAREOBJECT {RENAME}).
```

You must define ports before you use them. A define statement can include definitions of several ports. For example, if you have a design that contains five inputs (CLK, IN1, IN2, IN3, and IN4) and two outputs (OUT1 and OUT2), the define statement reads

```
(DEFINE INPUT PORT (MULTIPLE CLK IN1 IN2 IN3 IN4))
(DEFINE OUTPUT PORT (MULTIPLE OUT1 OUT2)).
```

You do not need the keyword "multiple" if you're defining only one input and one output.

After you have described the general features of your simulation, you can (finally!) specify the test patterns. Test patterns go into the "simulate" statement, which is a part of the interface section of the behavior view of an EDIF cell listing. The simulate section uses the keywords "wavevalue," "apply," and "logicwaveform" to create test patterns. The syntax of a simulate statement is

```
(SIMULATE SIMULATIONINFONAMEREF SIMULATENAMEDEF
  { <IGNOREVALUE> | WAVEVALUE | APPLY | COMMENT |
   PORTLISTALIAS | USERDATA | <RENAME> }).
```

The order of statements is important in the simulate block. You must specify what "ignorevalue," "portlistalias," and "wavevalue" stand for before you can use them in statements.

"Simulationinfonameref" is a reference to the name you specified in the place of "simulationinfonamedef" in your simulationinfo statement. In general, ". . . namedef" is the definition of a name; each ". . . nameref" is a later use of that name. The character string composing the name is the same in all cases; you simply regard the first occurrence as the definition.

In the place of "simulatenamedef," you give the name of the simulate block. In this section you specify a run number or a set of test patterns.

You can declare one, but only one, ignorevalue in each simulate block. For an input port, an ignorevalue means "don't apply"; for an output port, an ignorevalue means "don't care."

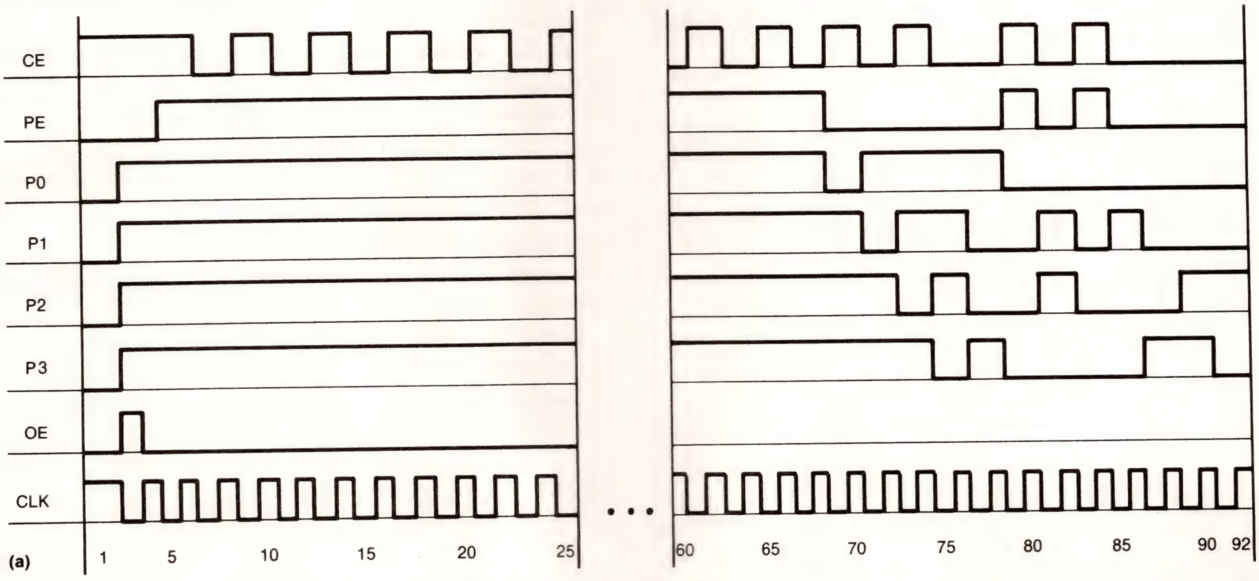
In the place of "portlistalias" you insert a name that represents a list of ports. This abbreviation minimizes redundant port-list specifications in a simulation file.

Apply waveforms to single lines or buses

In a "wavevalue" statement, you assign a logical state to a waveform fragment. Using the wavevalue statement, you can describe a pulse, a multicharacter logical state, or any other waveform fragment. The syntax of the wavevalue statement is

```
(WAVEVALUE LOGICNAMEDEF PERIOD LOGICWAVEFORM).
```

In the place of "period" you insert an integer that gives (in EDIF time units) the duration of each logic value in a logicwaveform. The total duration of a waveform is the product of the period and the number of logicnamerefs in a logicwaveform statement.



(b)
CE H(1-4), REPEAT HHLL(5-76), H(79-80), H(83-84)
PE L(1-4), L(69-78), L(81-82), L(85-92)
P0 L(1-2), L(69-70), L(79-92)
P1 L(1-2), L(71-72), L(77-80), L(83-84), L(87-92)
P2 L(1-2), L(73-74), L(77-80), L(83-88)
P3 L(1-2), L(75-76), L(79-86), L(91-92)
OE H(3)
CLK H(1-2), REPEAT HL(3-92)

__Fig 1—This set of input waveforms (a)__ tests the Moto2500 4-bit programmable binary counter; the numerical rendering __(b)__ gives the transitions. __Table 1__ gives the EDIF translation of these waveforms.

> *Logic states are part of the "technology" section of the library. You use the "simulationinfo" statement to specify these logic states.*

You use the logicwaveform statement to define the input patterns that you will apply to a logicnamedef (which you defined in your wavevalue statement). To create a clock pulse, you can write

```
(WAVEVALUE PULSE 1 (LOGICWAVEFORM H L)).
```

You may define a logicnameref only with the logic names that you declared in the simulationinfo section or as ignorevalues. You may not use a logicnamedef that you declared for an earlier wavevalue state. You may not nest wavevalue definitions.

You may use a wavevalue statement to describe any waveform. For example, if you want to express the waveform

```
C : LLLLL LLLLL LLLLL HHHHH HHHHH HHHHH HHHHH LLLLL
S : LL XX
P : LHHUXHL,
```

you write

```
(IGNOREVALUE X)
(WAVEVALUE C 5 (LOGICWAVEFORM L L L H H H H L)
(WAVEVALUE S 2 (LOGICWAVEFORM L X)
(WAVEVALUE P 1 (LOGICWAVEFORM L H H U X H L)).
```

If you have defined your EDIF time units as "scale time 1 (E 1 −9)," each time unit is 1 nsec. The duration of C is 40 nsec, the duration of S is 4 nsec, and the duration of P is 7 nsec.

States persist until you change them

Once you have set all the parameters of a simulation, you can apply your waveforms to your circuit. In the "apply" statements, you specify the applied input waveforms or the expected output response. The syntax of an apply statement is

```
(APPLY CYCLES PERIOD {LOGICINPUT} {LOGICOUTPUT}
                     {COMMENT} {USERDATA}).
```

In the place of "cycles" you give the number of cycles that you apply to the waveform. If you specify too few cycles in your logicwaveforms, the last-specified logic value of each port persists. If the period of a logic value in a logicwaveform doesn't last until a cycle ends, the simulation applies the final logic value until the cycle is over.

The keyword "logicinput" begins statements that define input waveforms. These statements specify the port to which you are applying a given logic waveform, and they include logicwaveform statements. The syntax of a logicinput statement is

```
(LOGICINPUT (PORTLIST | LISTNAMEREF) LOGICWAVEFORM),
```

where "portlist" is replaced by

```
(PORTREFERENCE | (MULTIPLE {PORTREFERENCE}))
```

and "listnameref" iterates the name given in place of "listnamedef" in the statement

```
(PORTLISTALIAS LISTNAMEDEF PORTLIST [RENAME]).
```

The logicwaveform specified in a logicinput statement is the same as the one specified in the wavevalue statement. In a logicinput statement, you use the logicnamedef that you defined in your wavevalue statement.

Groups of input ports

You can either list a design's ports in a portlist or use a listnameref to represent a group of ports in a portlistalias. Each port specified in a portlist or listnameref receives a value from the logicwaveform statement.

To simulate a design that has N ports, the logic simulator applies the first N logic values in the logicwaveform to the ports. The simulator holds each port in its initial state for the logic value's period, as specified in an apply statement.

In the second cycle of the simulation, the software applies logic value N+1 to the first port in the portlist or listnameref. The software continues loading the ports until it has applied a logic value to each port. After applying the second cycle's logic values to the ports for the length of time specified in the "period" section of the apply statement, the software continues the simulation until it has completed all the apply cycles.

If the period to apply a logic value lasts longer than the corresponding wavevalue, the last value in the wavevalue persists until the end of the period. If a logicwaveform ends before the simulator has completed all cycles, the simulator keeps each port in the last condition seen. For example, if you write

```
(APPLY 4 10
    (LOGICINPUT A (LOGICWAVEFORM U L H))),
```

you create the waveform

```
      CYCLE 1     CYCLE 2     CYCLE 3     CYCLE 4
A : UUUUUUUUUU  LLLLLLLLLL  HHHHHHHHHH  HHHHHHHHHH.
```

TABLE 1—EDIF FILE FOR 4-BIT COUNTER

```
(EDIF MOTO2500
  (DESIGN MOTO2500 (QUALIFY MOTO2500__LIBRARY MOTO2500__CELL))
  (LIBRARY MOTO2500__LIBRARY
    (STATUS (EDIFVERSION 1 1 0) (EDIFLEVEL 0)
      (WRITTEN (TIMESTAMP 1986 03 19 17 27 46 29)
          (ACCOUNTING AUTHOR "MOTOROLA ASIC PRODUCT GROUP")
          (ACCOUNTING PROGRAM "PAT2EDIF VERS M715.00.001 ***09/20/85***")))
    (TECHNOLOGY MOTO2500
      (SIMULATIONINFO MOTO 2500
          (SIMULATIONVALUE H L Z U)
          (ARBITRATE (PAIRWISE H H H H L L U Z U U))
          (ISOLATED Z))
      (COMMENT "H=HIGH, L=LOW, Z=HIGH IMPEDANCE, U=UNKNOWN"
               "THIS PAIRWISE REPRESENTS AN ECL TECHNOLOGY WIRED-OR")
      (NUMBERDEFINITION SI
          (SCALE TIME 1 (E 10 -9))))
    (CELL MOTO2500__CELL
      (STATUS (EDIFVERSION 1 1 0)(EDIFLEVEL 0)
          (WRITTEN (TIMESTAMP 1986 03 19 17 27 43 30)
              (ACCOUNTING AUTHOR "MOTOROLA ASIC PRODUCT GROUP")
              (ACCOUNTING PROGRAM "PAT2EDIF VERS M715.00.001 ***09/20/85***")
          )
      )
      (VIEW BEHAVIOR LOGIC
          (INTERFACE
              (DEFINE INPUT PORT (MULTIPLE CE PE P0 P1 P2 P3 OE CLK))
              (SIMULATE MOTO2500 FUNCTIONAL__TEST
                 (IGNOREVALUE X)
                 (APPLY 92 1
                    (LOGICINPUT CE
                       (LOGICWAVEFORM H H H H H H L L H H L L H H L L H H L L H
                        H L L H H L L H H L L H H L L H H L L H H L L H H L L H
                        H L L H H L L H H L L H H L L H H L L H H L L H H L L L
                        L H H L L H H L))
                    (LOGICINPUT PE
                       (LOGICWAVEFORM L L L L H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H L L L L L L L L L
                        L H H L L H H L))
                    (LOGICINPUT P0
                       (LOGICWAVEFORM L L H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H L L H H H H H H H
                        H L))
                    (LOGICINPUT P1
                       (LOGICWAVEFORM L L H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H L L H H H H L
                        L L L H H L L H H L))
                    (LOGICINPUT P2
                       (LOGICWAVEFORM L L H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H L L H H L
                        L L L H H L L L L L L H))
                    (LOGICINPUT P3
                       (LOGICWAVEFORM L L H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H H H H
                        H H H H H H H H H H H H H H H H H H H H H H H H H L L H
                        H L L L L L L L L H H H H L))
                    (LOGICINPUT OE
                       (LOGICWAVEFORM L L H L))
                    LOGICINPUT CLK
                       (LOGICWAVEFORM H H L H L H L H L H L H L H L H L H L H L
                        H L H L H L H L H L H L H L H L H L H L H L H L H L H L
                        H L H L H L H L H L H L H L H L H L H L H L H L H L H L
                        H L H L H L H L H L H L H L H)))
                 )(COMMENT "END APPLY")
              )(COMMENT "END SIMULATE")
          )(COMMENT "END INTERFACE")
      )(COMMENT "END CELL")
    )(COMMENT "END LIBRARY")
  )
```

Once you have completed your technology block, you can describe the input and output ports of your cells.

Because the logicwaveform ended before the final cycle, the value H persisted to the end of the period.

Waveforms and pulses obey the same rules

The same rules that apply to a single logic value apply to a complex logicwaveform. For example, if you write

```
(IGNOREVALUE X)
(WAVEVALUE C 2 (LOGICWAVEFORM H H H L L L H))
(APPLY 3 20
   (LOGICINPUT B (LOGICWAVEFORM H C X))),
```

you create the waveform

```
            CYCLE 1                        CYCLE 2
B : HHHHHHHHHHHHHHHHHHHH   HHHHHHLLLLLLHHHHHHHH

            CYCLE 3
    XXXXXXXXXXXXXXXXXXXX.
```

Because the logicwaveform C ends before the period ends, the value H persists to the end of the period.

You can use these rules to apply waveforms to several ports simultaneously. For example, if you write

```
(APPLY 4 10
   (LOGICINPUT (MULTIPLE B D E)
               (LOGICWAVEFORM H H H L L L U X H H))),
```

you create the series of waveforms

```
      CYCLE 1      CYCLE 2      CYCLE 3      CYCLE 4
B : HHHHHHHHHH   LLLLLLLLLL   UUUUUUUUUU   HHHHHHHHHH
D : HHHHHHHHHH   LLLLLLLLLL   XXXXXXXXXX   XXXXXXXXXX
E : HHHHHHHHHH   LLLLLLLLLL   HHHHHHHHHH   HHHHHHHHHH.
```

The logicwaveform applies successive values to ports B, D, and E. B receives the first, fourth, seventh, and tenth values; D receives the second, fifth, and eighth values; and E receives the third, sixth, and ninth values. Because the logicwaveform is applying a third cycle to ports D and E, these ports remain in the last state of their respective waveforms until the end of the cycle.

You can use these rules to clear a circuit. To do so, you write

```
(APPLY 50 0
   (LOGICINPUT IN1 (LOGICWAVEFORM L)).
```

By setting the period to zero, you apply the waveform to the network until it settles.

In addition to applying signals to a circuit, you can analyze the response of your circuit to an applied signal. A "logicoutput" statement compares the expected response of a circuit and the results of the simulation. An EDIF file reports a match of the simulated response and the logicoutput or expected response if the two waveforms match at any time during a cycle. The syntax of logicinput and logicoutput statements is the same in each case.

Consider the following example. In the file

```
(SIMULATIONVALUE H L G)
(IGNOREVALUE X)
(WAVEVALUE C 1 (LOGICWAVEFORM L L L H H H H L))
(WAVEVALUE S 1 (LOGICWAVEFORM L G))
(APPLY 5 10
   (LOGICOUTPUT YAOUT (LOGICWAVEFORM X H L C S)),
```

you are setting output YAOUT to look like

```
YAOUT : XXXXXXXXXX HHHHHHHHHH LLLLLLLLLL LLLHHHHLLL
                                         LGGGGGGGGG LGGGGGGGGG.
```

To achieve a match between the expected value of YAOUT and the results of the simulation, YAOUT can be any legal value during the first cycle, but it must reach the value H at some time during the second cycle. At some time during the third cycle, YAOUT must be L. During the fourth cycle, YAOUT must be L in the first three units, H in the next four units, or L in the next three units. Finally, YAOUT must be L in the first unit or G in the last nine units of the fifth and sixth cycles.

By combining portlistalias, logicinput, and logicoutput statements, you can create almost every logic waveform. For example, if you write

```
(PORTLISTALIAS INPUTS (MULTIPLE A1 A2 A3 A4 B1 B2))
(PORTLISTALIAS OUTPUTS (MULTIPLE OUT1 OUT2))
(WAVEVALUE M 2 (LOGICWAVEFORM L L L H L))
(WAVEVALUE S 5 (LOGICWAVEFORM H L))
(APPLY 4 10
   (LOGICINPUT INPUTS (LOGICWAVEFORM L L L L H H
                       M L S L L H  H H S H ))
   (LOGICOUTPUT OUTPUTS (LOGICWAVEFORM X X   L H
                         M S  L)),
```

your input waveforms and expected output waveforms are

```
A1   : LLLLLLLLLL   LLLLLLHHLL   HHHHHHHHHH   HHHHHHHHHH
A2   : LLLLLLLLLL   LLLLLLLLLL   HHHHHHHHHH   HHHHHHHHHH
A3   : LLLLLLLLLL   HHHHHLLLLL   HHHHHLLLLL   HHHHHLLLLL
A4   : LLLLLLLLLL   LLLLLLLLLL   HHHHHHHHHH   HHHHHHHHHH
B1   : HHHHHHHHHH   LLLLLLLLLL   LLLLLLLLLL   LLLLLLLLLL
B2   : HHHHHHHHHH   HHHHHHHHHH   HHHHHHHHHH   HHHHHHHHHH
OUT1 : XXXXXXXXXX   LLLLLLLLLL   LLLLLLHHLL   LLLLLLLLLL
OUT2 : XXXXXXXXXX   HHHHHHHHHH   HHHHHLLLLL   HHHHHLLLLL.
```

The portlistalias definitions let you condense several

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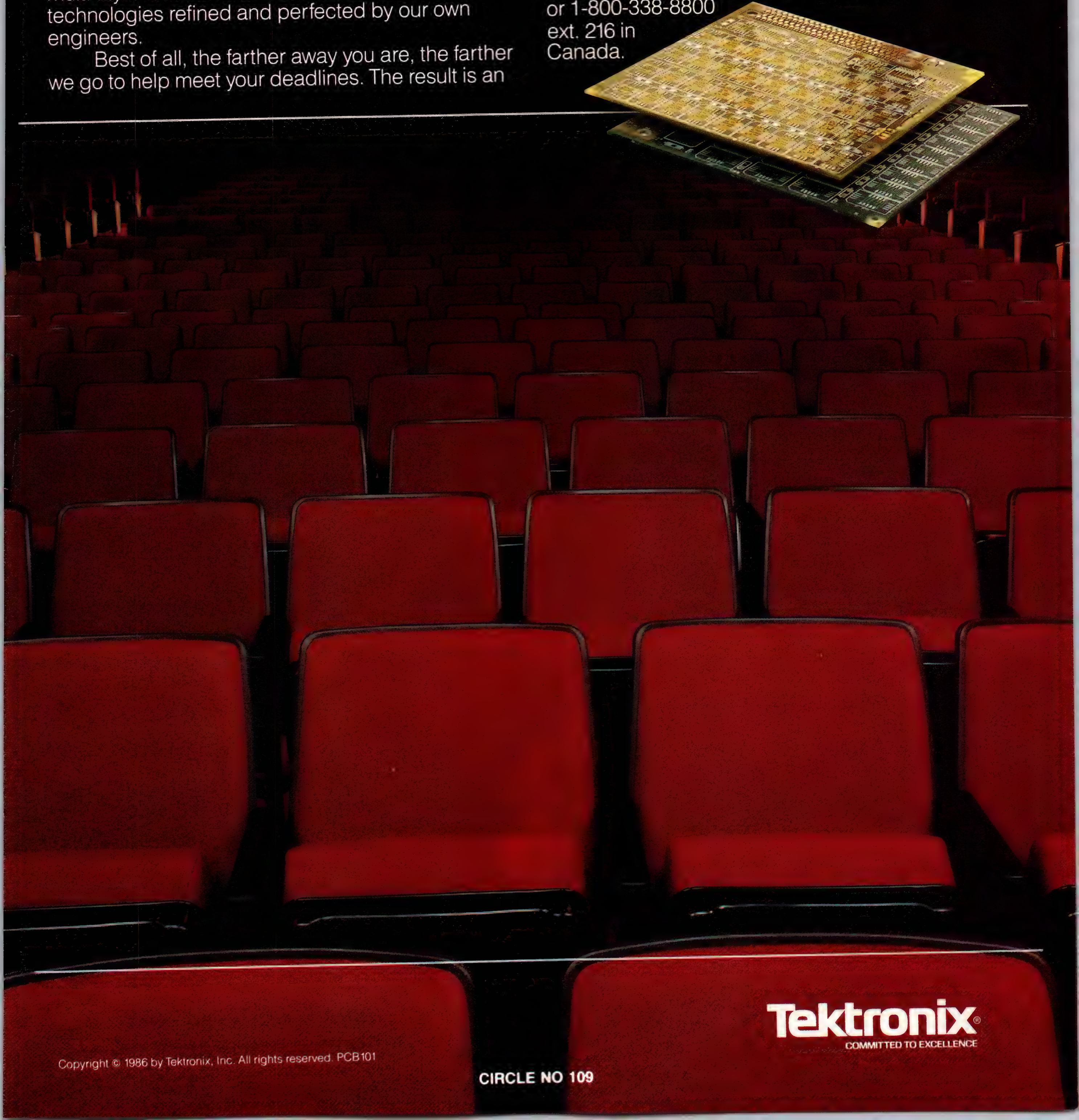

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CIRCLE NO 109

To simulate a design that has N ports, the logic simulator applies the first N logic values in the logicwaveform to the ports.

TABLE 2—COMPRESSED EDIF FILE FOR 4-BIT COUNTER

```
(EDIF MOTO2500
        :
  (WAVEVALUE PULSE 1 (LOGICWAVEFORM H L))
  (IGNOREVALUE X)
  (APPLY 46 2
    (LOGICINPUT CE
      (LOGICWAVEFORM H H H L H L H L H L H L H L H L H L H L H
       L H L H L H L H L H L H L H L H L L H L H L))
    LOGICINPUT PE
      (LOGICWAVEFORM L L H H H H H H H H H H H H H H H H H H H
       H H H H H H H H H H H H H L L L L L H L H L))
    (LOGICINPUT P0
      (LOGICWAVEFORM L H H H H H H H H H H H H H H H H H H H H
       H H H H H H H H H H H H H L H H H H L))
    (LOGICINPUT P1
      (LOGICWAVEFORM L H H H H H H H H H H H H H H H H H H H H
      H H H H H H H H H H H H H H L H H L L H L H L))
    (LOGICINPUT P2
      (LOGICWAVEFORM L H H H H H H H H H H H H H H H H H H H H
       H H H H H H H H H H H H H H H L H L L H L L L H))
    LOGICINPUT P3
      (LOGICWAVEFORM L H H H H H H H H H H H H H H H H H H H H
      H H H H H H H H H H H H H H H H L H L L L L H H L))
    (LOGICINPUT OE
      (LOGICWAVEFORM L H L))
    (LOGICINPUT CLK
      (LOGICWAVEFORM PULSE)))
)(COMMENT "END APPLY")
        :
)
```

statements into one line. The first group of waveforms, LLLLHH, contains the first values that you are applying to the inputs. The second group of waveforms, MLSLLH, contains the values that you are applying to the inputs in the second cycle. You use the same syntax to analyze the response at the output ports.

For purposes of illustration, it's worth looking at the EDIF files that present the test vectors for a device that contains several gates. The example is a 4-bit programmable binary counter, the Motorola Moto2500, which has eight inputs and five outputs. (You can, of course, simulate a much more complex circuit than a counter.)

The inputs are CE (clock enable), PE (programmable-input enable), OE (output enable), CLK (clock), and P0 to P3. The outputs are TL (total count) and Q0 to Q3. CE, PE, and OE enable their respective input lines when they are low. P0 and Q0 are the respective least significant data bits; P3 and Q3 are the respective most significant data bits. TL is low only when the four output bits are all high.

To apply the test patterns shown in **Fig 1a** on page 187 to this device (**Fig 1b**'s numerical rendering specifies the transitions), you write the EDIF file given in **Table 1** on page 189.

Because this test forces the outputs to zero (OE is low during time step 3), you can't compress the logicwaveforms. If you give OE the test pattern H(3-4), you can compress the waveforms and change the EDIF file to the form given in **Table 2.**

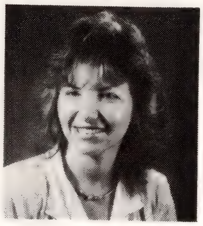
You should now know how to create component libraries, how to transfer component libraries, and how to transfer test vectors using EDIF. The final article will explain how you can develop EDIF interfaces for your own CAD operation. **EDN**

References

1. Marx, Esther, Hart Switzer, and Mike Waters, "EDIF format brings uniformity to CAE/CAD data," *EDN*, January 22, 1987, pg 153.

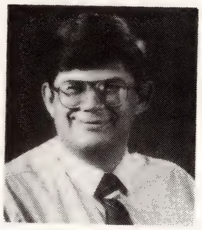
2. Marx, Esther, Hart Switzer, and Mike Waters, "Use an interchange format to port component libraries," *EDN*, February 5, 1987, pg 175.

Authors' biographies



Esther Marx is a senior software engineer for Motorola Semiconductor Product Sector's ASIC Division (Mesa, AZ). She received an MS from George Washington University (Washington, DC) and a BA from Oberlin College (Oberlin, OH). Before joining Motorola, Esther served for five years in the Air Force. She enjoys writing science fiction and collecting Star Trek memorabilia.

Hart Switzer is a software engineer with Motorola Semiconductor Products, where she designs and implements EDIF software. She received a BS from Stanford University (Palo Alto, CA). Hart enjoys gardening and collecting antiques.



Mike Waters is a principal engineer and EDIF project manager at Motorola Semiconductor Products. He received a BS in computer science from Regent's College in New York. Mike likes to exchange ideas with other EDN readers via his ham radio (license AA4MW) or his amateur packet radio.

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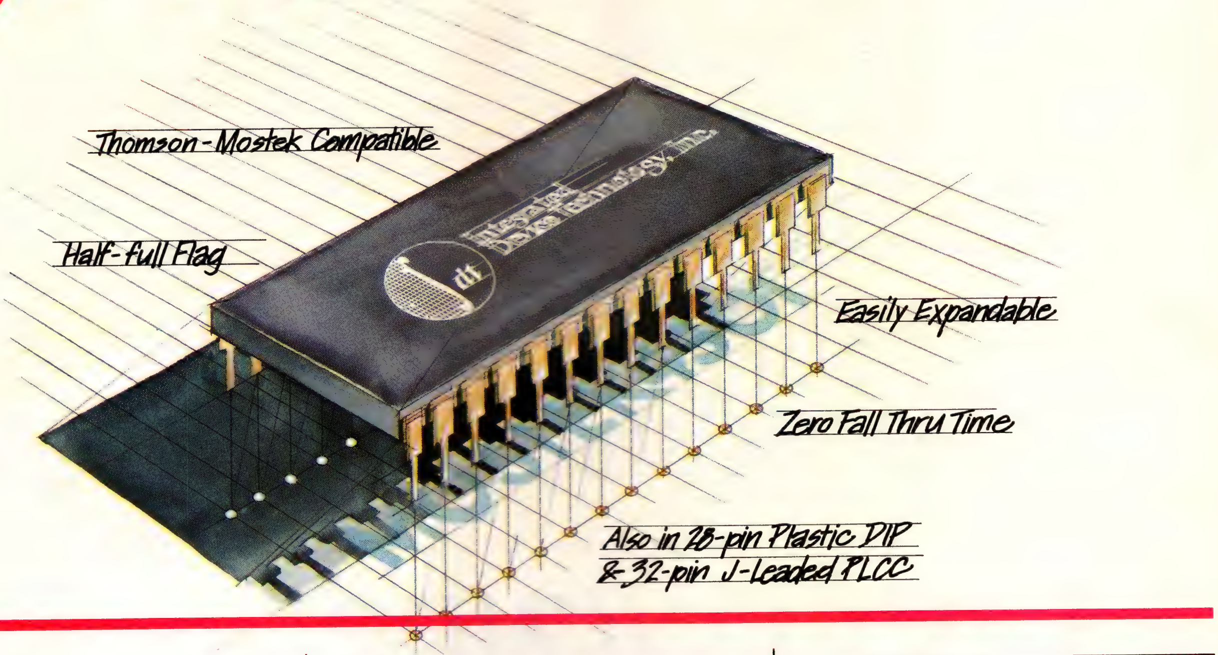
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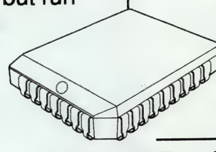

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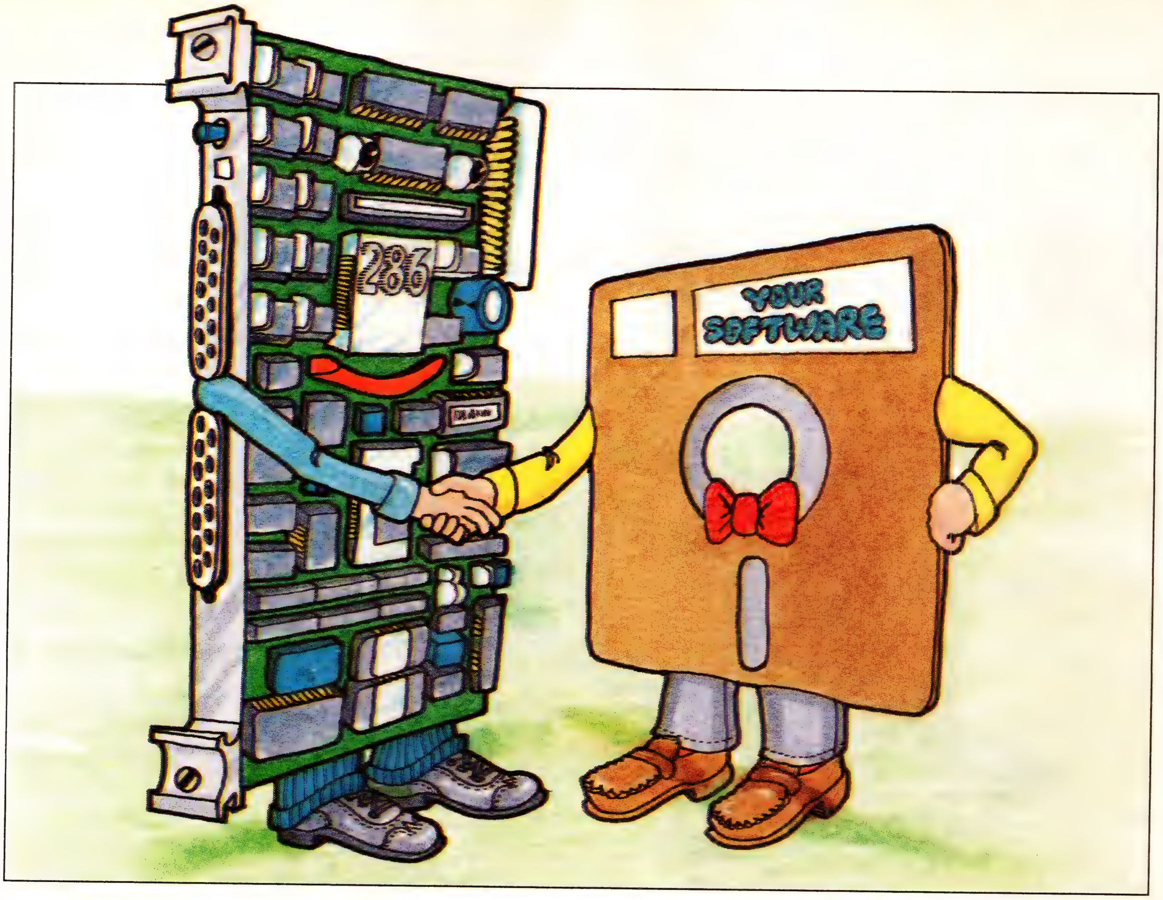

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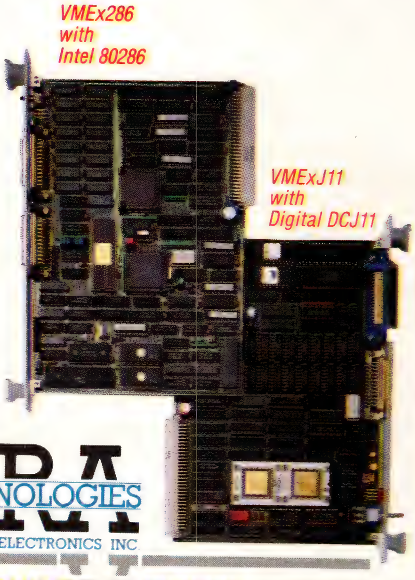

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CIRCLE NO 111

EDITED BY TARLTON FLEMING

Tree structure detects multiple inputs

P J Reilly
Kaiser Electronics, San Jose, CA

The logic gates that make up the tree structure of **Fig 1** present an elegant solution to the problem of how to determine when more than one of a group of inputs is simultaneously active. (The alternative product-of-terms equation becomes unmanageably large for more than a small number of inputs.)

You form the tree with "either/both" cells, using as many as necessary to accommodate any reasonable number of inputs. Each cell consists of one OR and one AND gate **(Fig 2)**, which simply indicates whether either or both of the cell's inputs are active. Each "either" output forms an input to the next level of the tree. Any "both" output that is active indicates more than one input to the tree is active, so all "both" outputs are collected in a large multiple-input OR gate to form the circuit's output signal.

For some circuit technologies, it may be appropriate to use NAND and NOR gates instead of AND and OR types and to invert the definition of signals at each level of the tree. **EDN**

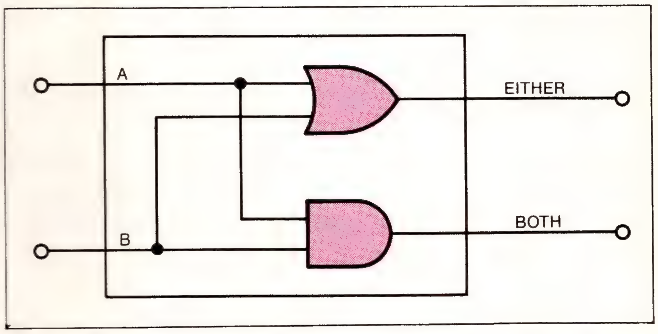

Fig 2—Each "either/both" cell in Fig 1 includes simply an AND gate and an OR gate.

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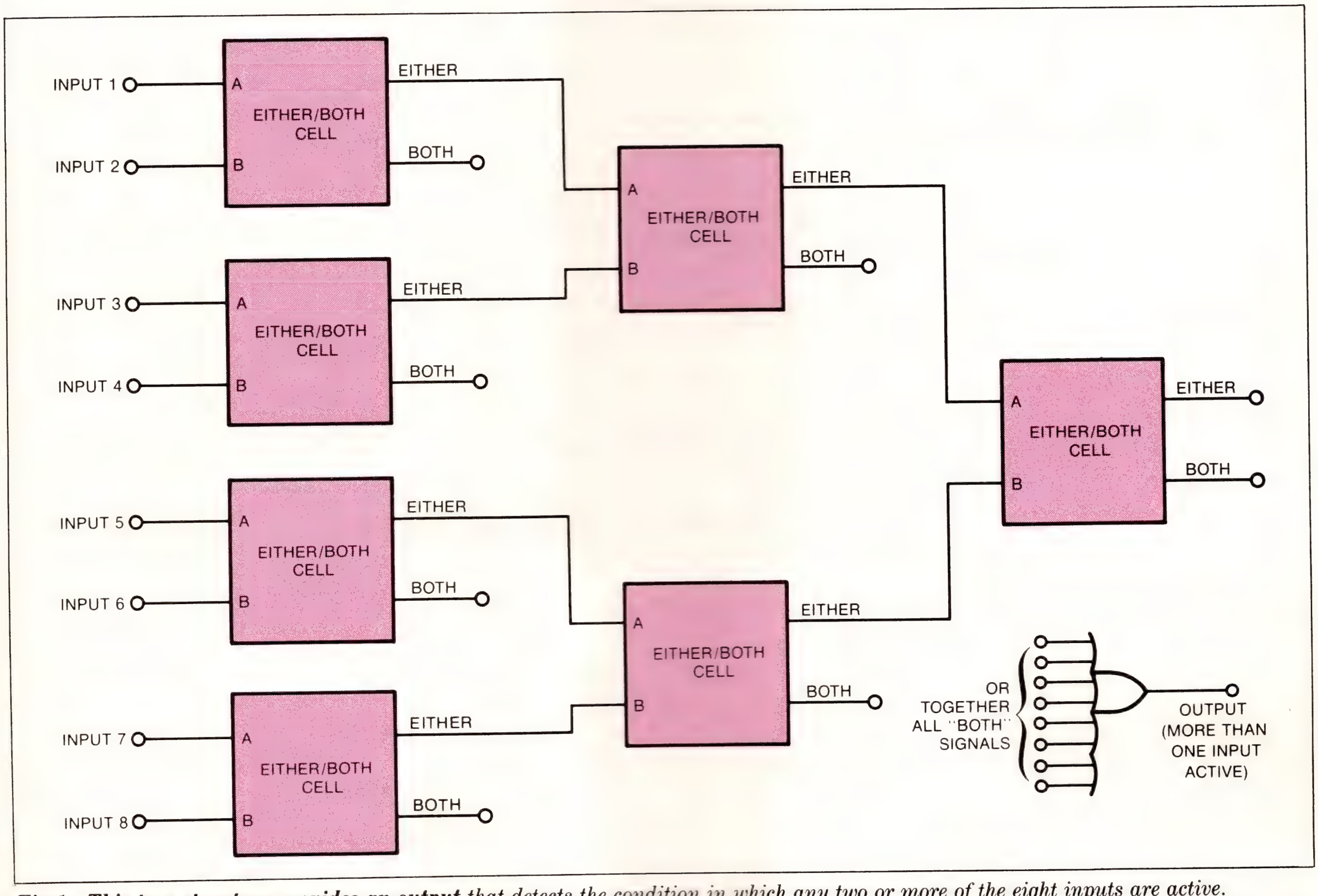

Fig 1—This tree structure provides an output that detects the condition in which any two or more of the eight inputs are active.

Isolation amp uses balanced modulators

Moshe Gerstenhaber, Steve Miller,
and Chuck Kitchen
Analog Devices Semiconductor, Wilmington, MA

The isolation amplifier of **Fig 1** can faithfully transfer low-frequency information across a potential of 3 kV or more. Over the ±10V V_{IN} range, V_{OUT} deviates no more than 350 μV—that is, less than 0.0018%, which corresponds to a linearity of better than 14 bits. Offset-voltage drift and gain drift are less than 2 ppm and 50 ppm/°C, respectively. Typical bandwidth and output noise are 35 Hz and 1 mV rms. If necessary, you can improve these two specs by optimizing the output-filter characteristics.

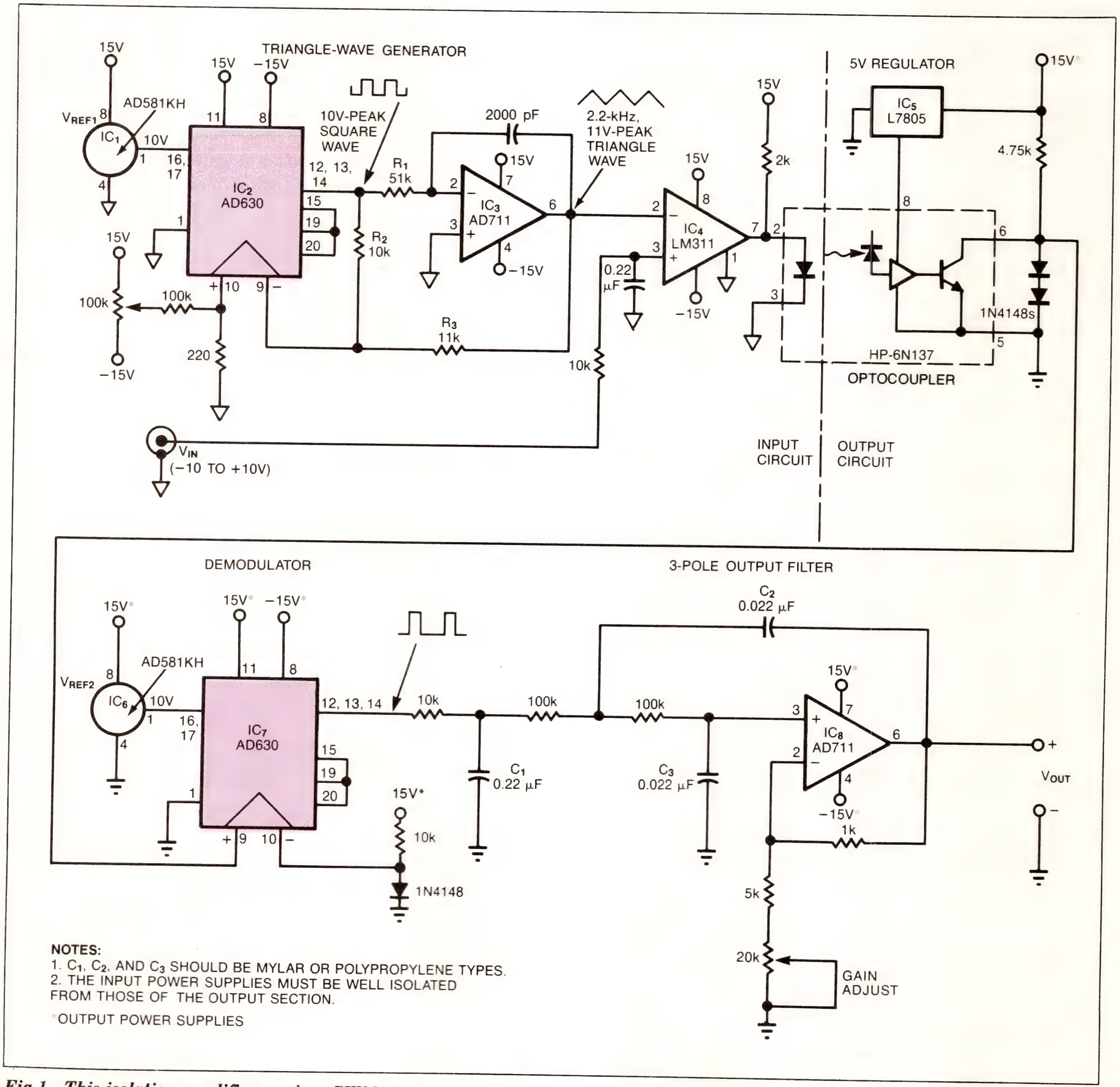

Fig 1—This isolation amplifier *employs PWM and optocoupling to transfer low-frequency signals across a barrier of 3 kV or more.*

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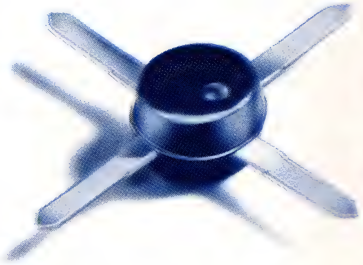

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MAR-7	DC-2000	8.5	+4	5.0	1.90	(25)
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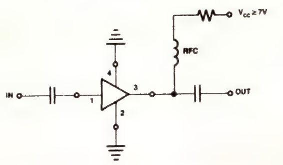

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Each balanced modulator (IC_2 and IC_7) is connected as a ±unity-gain block **(Fig 2)**. IC_2 and op amp IC_3 constitute a triangle-wave generator that produces a 2.2-kHz, 11V pk waveform at the inverting input of comparator IC_4. With V_{IN} applied to its other input, the comparator produces a PWM output in which V_{IN} is encoded as a duty cycle.

This modulated signal passes through the optocoupler and, together with 10V from reference IC_6, directly drives IC_7, the second modulator. IC_7's ±10V output **(Fig 3)** has a duty cycle that corresponds precisely to V_{IN}. Finally, the 3-pole, lowpass output filter reconstructs V_{IN} by extracting the duty-cycle waveform's average value.

Because the isolation amplifier's linearity depends on duty-cycle ratios, variations of waveform frequency and amplitude have negligible effect on the circuit's accuracy. What's more, the precision voltage references (IC_1 and IC_6) provide a temperature-stable output. The isolation amplifier's transfer function is

$$V_{OUT} = \frac{V_{IN}(V_{REF2})}{V_{REF1}(R_3/R_2)}\,(1.1).$$

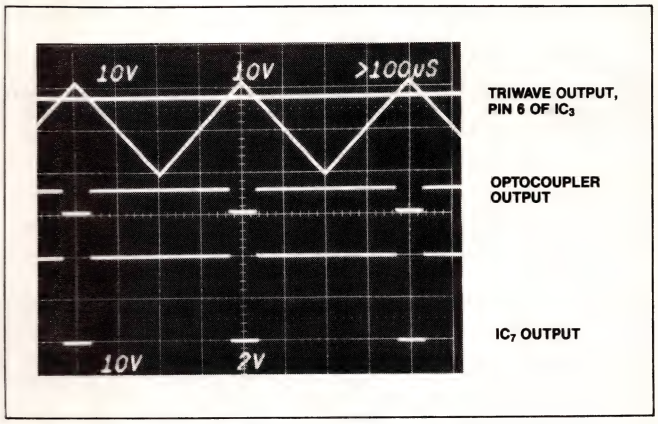

Fig 3—Looking at these waveforms, *you can see how the* ***Fig 1*** *circuit uses PWM to encode V_{IN} as a duty cycle.*

Excessively low duty cycles degrade linearity. So, resistors R_2 and R_3 set the triangle-wave amplitude (IC_3, pin 6) to 11V peak, which sets a minimum duty cycle for ±10V inputs. To restore the proper output level, you set the filter gain to 1.1 by adjusting the 20-kΩ potentiometer. **EDN**

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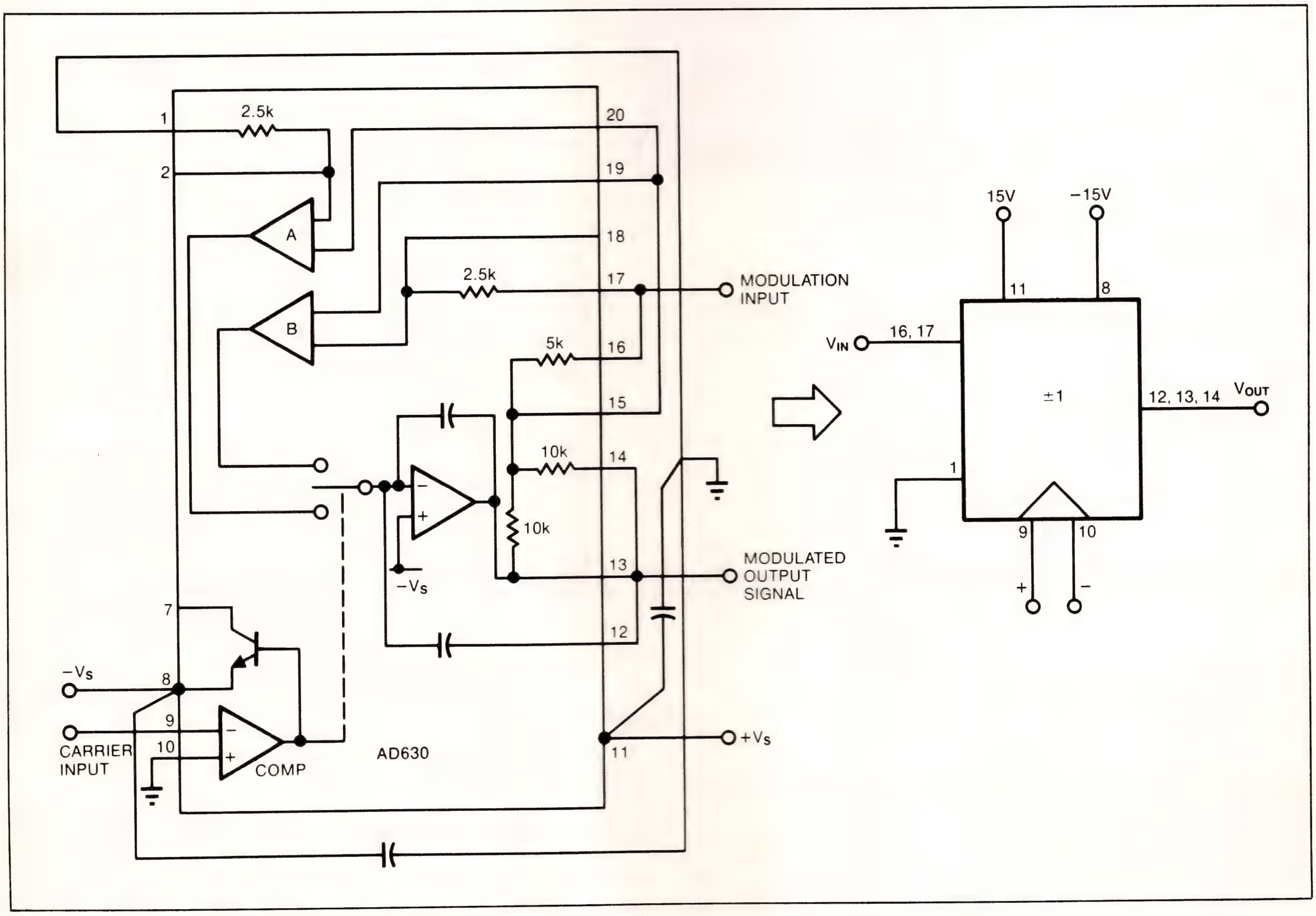

Fig 2—This balanced modulator/demodulator *is configured as a ±unity-gain device.*

Signal conditioner borrows power from host

Albert Helfrick
Dowty-RFL Industries, Boonton, NJ

The circuit of **Fig 1** addresses a common data-acquisition problem: how to condition a remote, low-duty-cycle signal for transmission back to the host system without installing dedicated power-supply lines for the conditioning circuit. As an added benefit, hysteresis at the input (pin 4) of the CMOS one-shot, IC_1, accommodates signals with slow rise and fall times.

Between input pulses, capacitor C_1 borrows charge from the host system's 5V supply to provide a V_{DD} voltage at pin 16 of IC_1. The charging current flows through R_5, the coaxial cable, R_4, and R_3. Following power turn-on, these resistors limit the surge current to 10 mA as required by the 4538 monostable multivibrator. (Other one-shots may have a lower current rating; for these, you can divert part of the turn-on surge by connecting an external diode in parallel with the internal protection diode.) As C_1 approaches full charge, the charge current flows through a p-channel MOSFET in IC_1 instead of the protection diode.

The V_{DD} voltage decreases as the one-shot's output duty cycle increases. However, the timing components shown (R_2 and C_2) and, for example, a 0.5-Hz rate of phototransistor events, produce a duty cycle of 0.1%, which has little effect on the V_{DD} voltage. **EDN**

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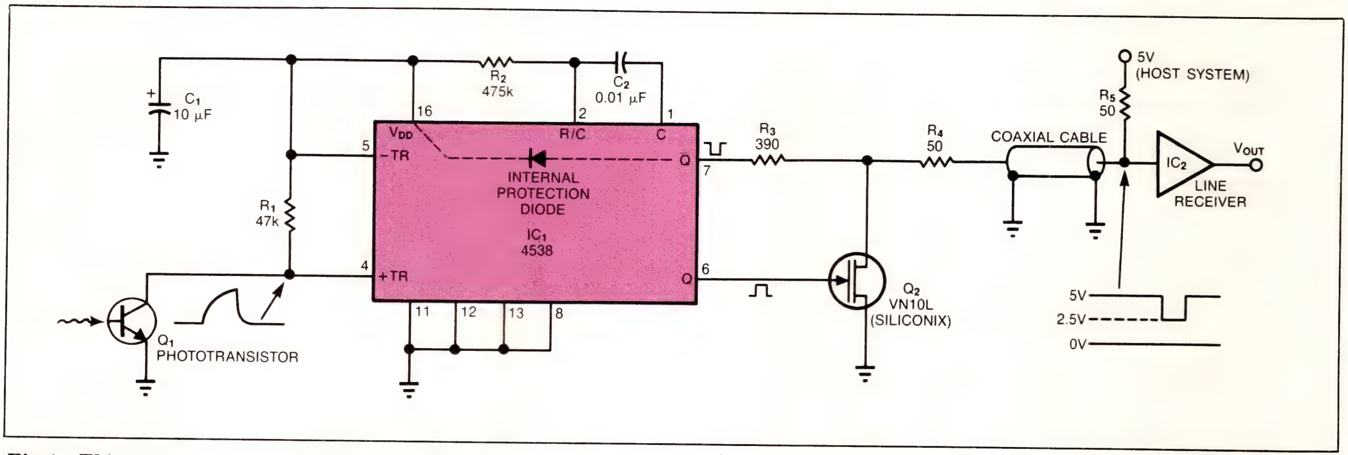


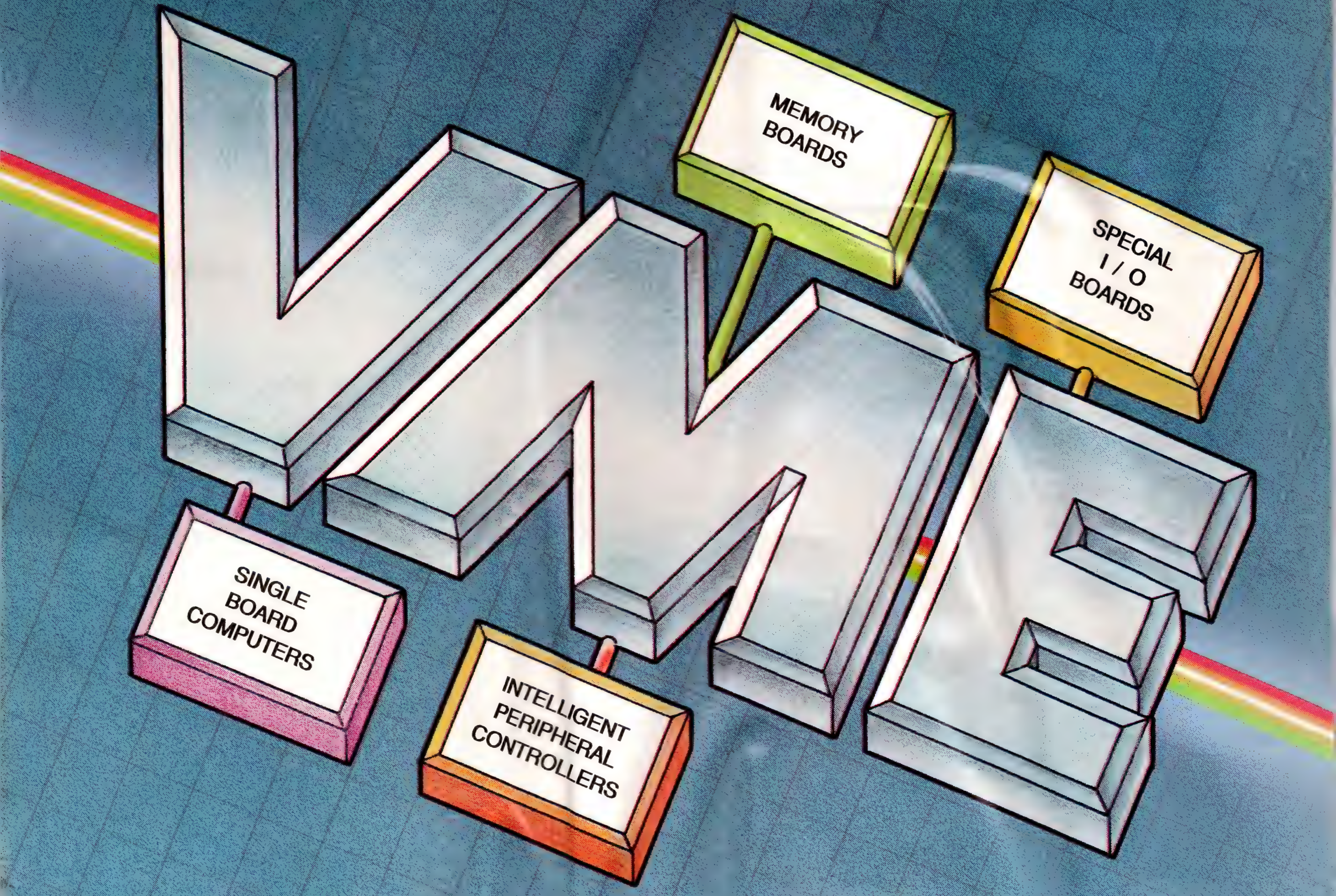
***Fig 1—This remote signal-conditioning circuit** borrows power from the host system between input pulses by charging C_1 through the signal cable.*

Software routine probes TMS32010 code

Roy McCammon
3M Co, Austin, TX

Two software macros (**Listing 1**) let you probe the data generated by a TMS32010 µC program in a manner analogous to the way an oscilloscope probes the circuit nodes of an analog filter. Just as the scope can reveal oscillating or saturated amplifier stages and noise in the analog circuit, the software technique can reveal similar problems in a digital filter by probing its intermediate state variables.

Your target system must include a spare input port (PA5 in **Listing 1**) for designating the state variable to be probed and a spare output port (PA6) for receiving the state variable's value. For example, a personal computer can query the system by supplying variable names to the PA5 port. A D/A converter connected to the PA6 port can reconstruct the variable values for



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CIRCLE NO 113

display on an oscilloscope.

The Probe macro has two parameters: the number of the probe and the RAM location to be probed. Each time during execution that the probe number matches the number at PA5, the macro fetches the variable value from that location and stores it at the TEMP2 location. Then, the following interrupt macro's first instruction outputs this value (listing the instruction first results in a fixed software delay for the output operation).

You can sprinkle the probes throughout your interrupt code, but keep in mind that they use up program space and execution time. You need two temporary RAM locations: TEMP2 (dedicated to the probes) and *TEMP1*. Other requirements are as follows: seven words of program memory per probe, six machine cycles per unselected probe, eight cycles per selected probe, one RAM location for the first probe, one extra program-memory location, and two extra cycles for the OUT instruction.

Number the probes in order of importance, designating the lowest numbers as the most important. Then, you can select a subset of probes by reassembling with MAXPRB set to a desired number; only probes with numbers less than MAXPRB will be assembled. You can deactivate all probes by setting MAXPRB to zero. To proceed, assemble and link the program, begin execution, and then set PA5 to enable the desired probes. **EDN**

To Vote For This Design, Circle No 749

LISTING 1—PROBE ROUTINE

```
MAXPRB  EQU     >20     ENABLE PROBE NUMBERS LESS THAN 32
        .
        .
        .
PROBE   $MACRO  C,WORD
        $IF     C.V<MAXPRB
        UNL                     TURN OFF LISTING.
        IN      TEMP1,PA5       TRANSFER VALUE AT PA5 TO TEMP1.
        LACK    :C.V:           LOAD ACCUMULATOR IMMEDIATE WITH
*                               THE NUMBER OF THIS PROBE.
        SUB     TEMP1           SUBTRACT STORED VALUE OF PA5.
        BNZ     $+4             IF THE STORED VALUE OF PA5 IS
*                               NOT THE SAME AS THE NUMBER OF
*                               THIS PROBE, THEN THIS PROBE IS
*                               NOT THE DESIRED PROBE.
        LAC     :WORD.S:        GET THE VALUE OF THE DESIRED
*                               VARIABLE.
        SACL    TEMP2           PUT THE DESIRED VARIABLE
*                               AT TEMP2.
        LIST                    TURN ON LISTING.
        $ENDIF
        $END
        .
        .
        .
IRQ             first of interrupt routine
        .
        .
        .
        OUT     TEMP2,PA6       OUTPUT PROBE VALUE FROM PREVIOUS
*                               INTERRUPT.
        .
        .
        .
        PROBE   >7,FILTER1      OUTPUT FILTER1 IF PA5
*                               IS 7.
        .
        .
        .
        PROBE   >A,(FILTER2,3)  OUTPUT FILTER2 LEFT SHIFTED
*                               3 BITS IF PA5 IS 10.
        .
        .
        .
        RET                     RETURN FROM INTERRUPT
```

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DANGER
DANGER
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PUSH BUTTON TO OPEN DOOR
"T" HANDLE OUT 9 FEET
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CIRCLE NO 164

Two-way amplifier uses few parts

Rudy Stefenel
Luma Telecom, Santa Clara, CA

Fig 1 depicts a conventional 2-way amplifier used with 2-wire telephone lines. This approach requires separate amplifiers for each direction, hybrid 2- to 4-line transformers, and carefully designed complex-impedance terminations to match the capacitive reactance normally associated with telephone lines.

For 2-wire signal lines whose impedance is mostly resistive (telecommunications test equipment, for example), you can use the simpler, resistively terminated circuit of **Fig 2.** The boxes labeled "termination" are two telecomm devices (such as modems, modem test equipment, short-haul 2-wire communication lines, or minimum-loss impedance-matching pads) that are communicating with each other.

Like all 2-way amplifiers, both of these circuits may oscillate unless terminated with the proper impedance. Moreover, higher audio gain imposes greater accuracy constraints on the terminating impedance values. Because resistors R_A, R_B, R_C, and R_D have a fixed relationship with one another, you can set the circuit's "resistance level" by choosing a value for one of them—R_D, for example. Given the desired termination resistance R_L and amplifier gain A, you can then calculate values for the remaining resistors R_A, R_B, and R_C.

First, note that R_A contributes the only significant resistance between each amplifier and its load. Source impedance should equal the load impedance, so

$$R_A=R_L \tag{1}$$

is the first of three design equations. Because IC_2 mustn't contribute a signal while IC_1 is operating (and vice versa), IC_2's output must remain at virtual ground during that time. Therefore, R_A is also the input impedance for each amplifier.

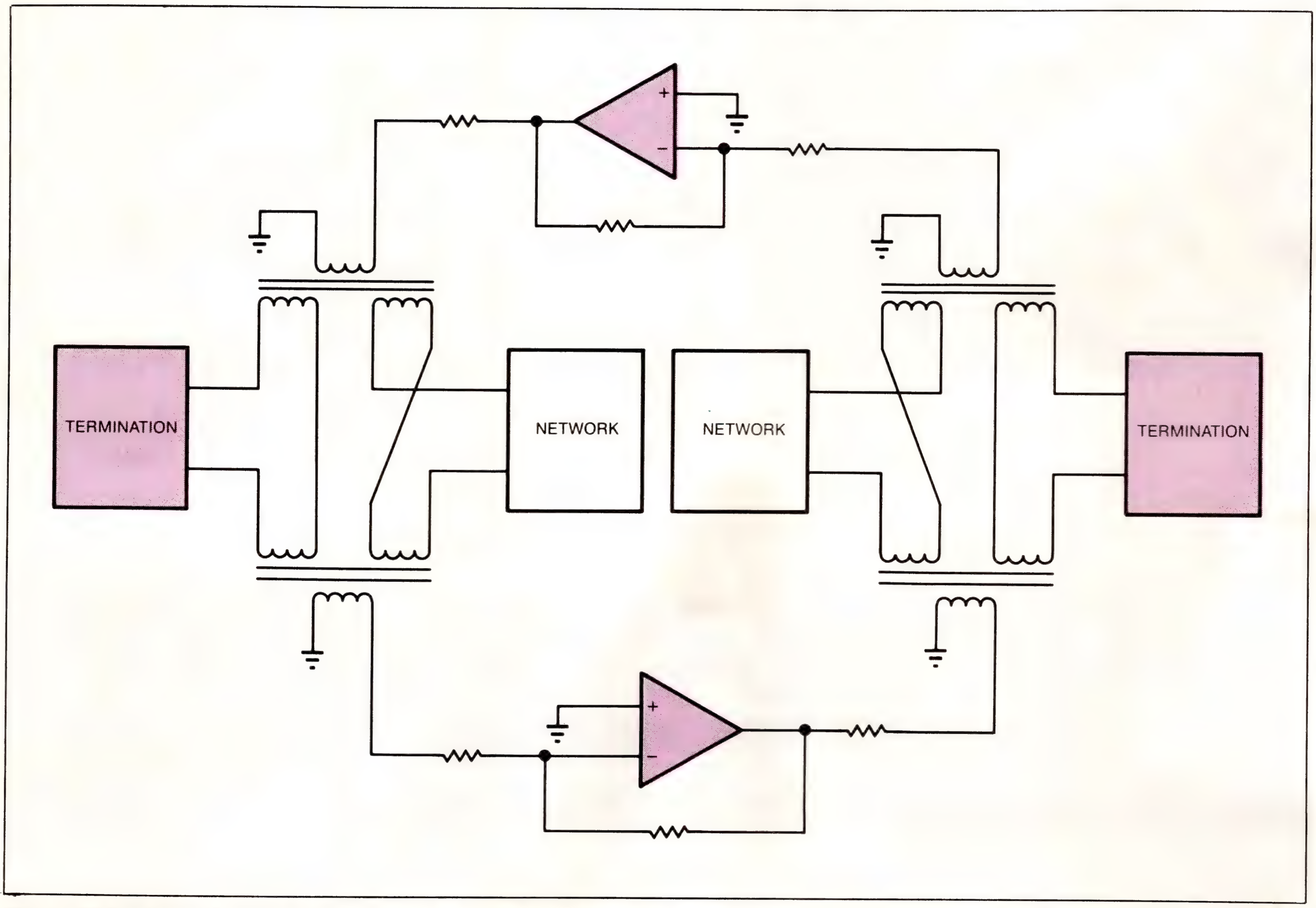

*Fig 1—**This schematic shows a typical 2-way amplifier** used with telephone lines.*

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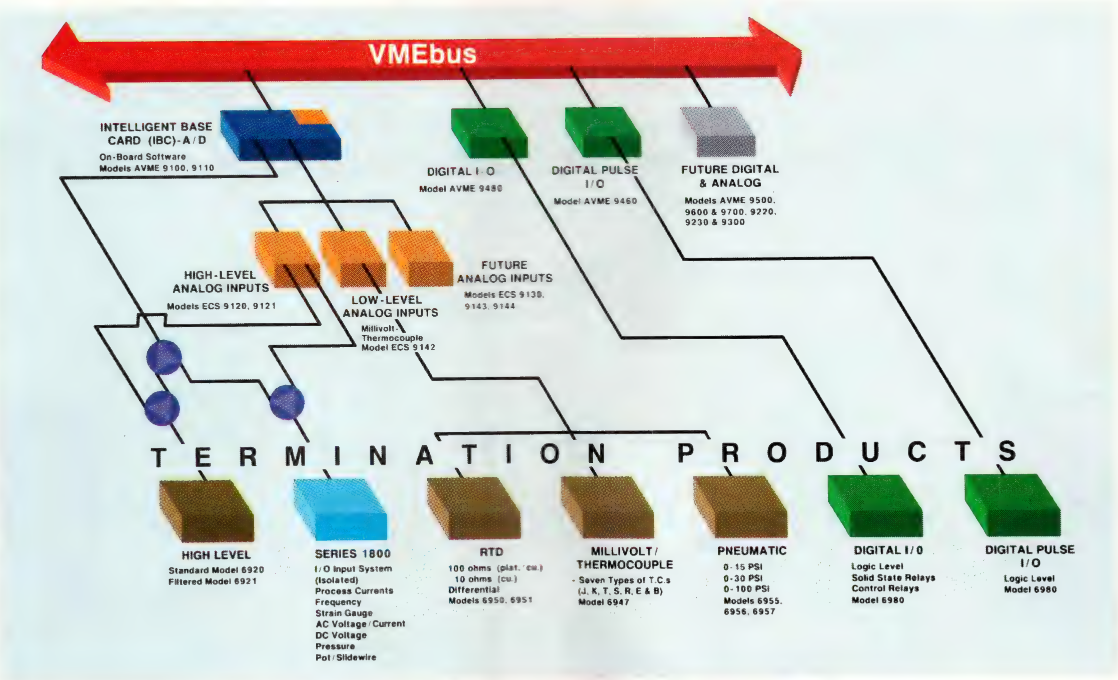

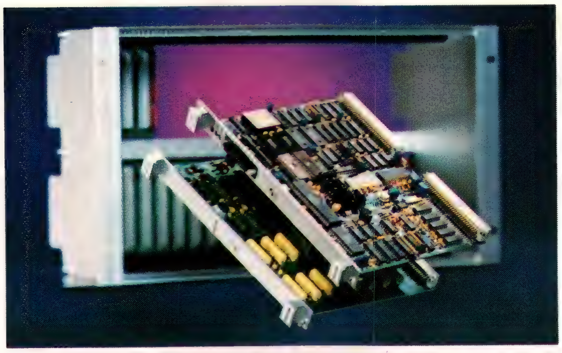

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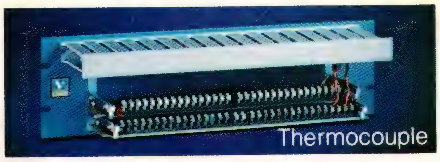

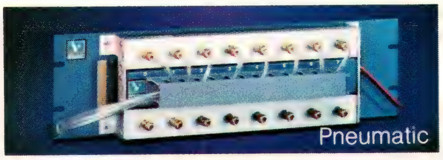

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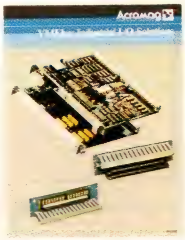

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CIRCLE NO 116

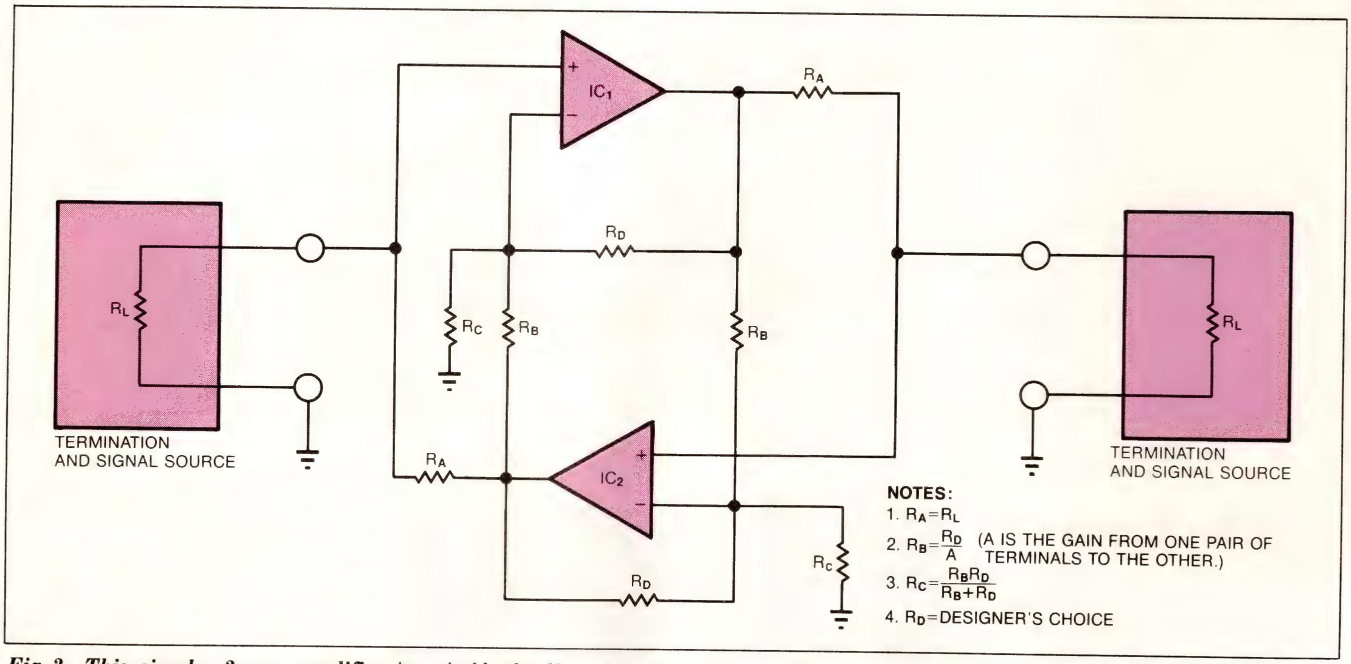
Next, the gain from IC_1's noninverting input to its output is

$$\frac{R_D+\frac{R_CR_B}{R_C+R_B}}{\frac{R_CR_B}{R_C+R_B}},$$

and the gain from IC_1's output to R_L is ½ because $R_A=R_L$ (**Eq 1**). The product of these gains must equal the given gain A:

$$A=\frac{1}{2}\left[\frac{R_D+\frac{R_CR_B}{R_C+R_B}}{\frac{R_CR_B}{R_C+R_B}}\right]. \qquad (2)$$

To ensure that no signal is emitted from IC_2 when only the lefthand signal source is active, IC_2's differen-



NOTES:
1. $R_A=R_L$
2. $R_B=\frac{R_D}{A}$ (A IS THE GAIN FROM ONE PAIR OF TERMINALS TO THE OTHER.)
3. $R_C=\frac{R_BR_D}{R_B+R_D}$
4. R_D=DESIGNER'S CHOICE

Fig 2—This simpler 2-way amplifier *is suitable for lines whose impedance is primarily resistive.*

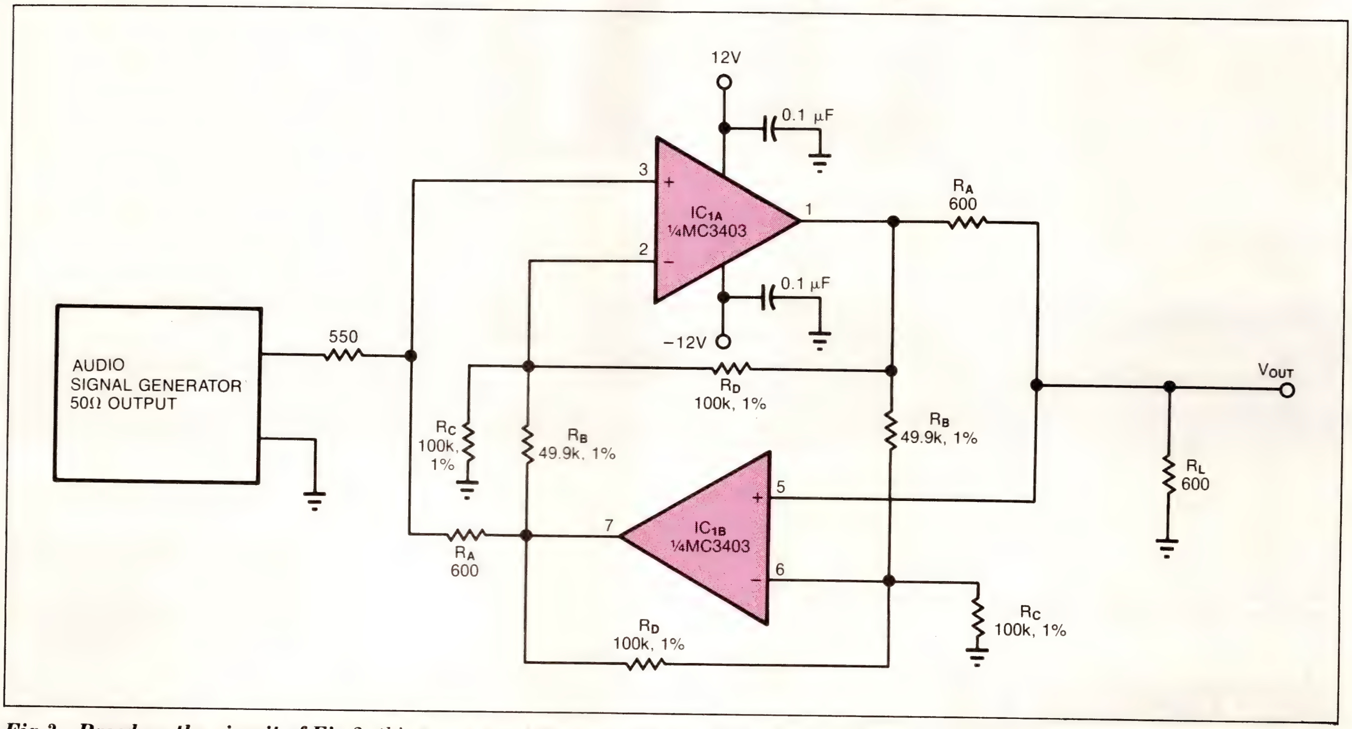


Fig 3—Based on the circuit of Fig 2, *this 2-way amplifier provides a gain of 2 between 600Ω terminations.*

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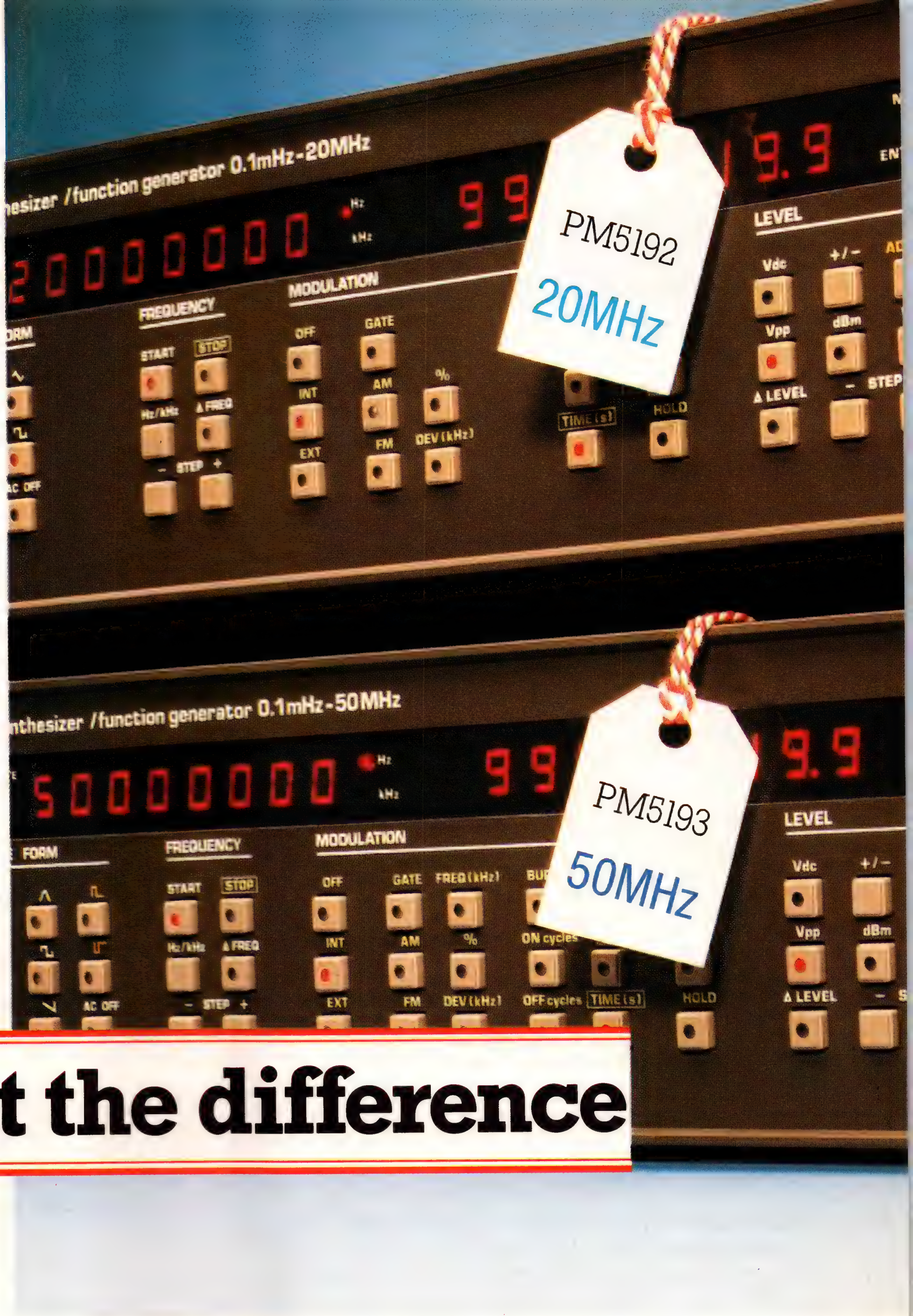

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tial input must be zero. This is so if IC_2's inputs are equal, which implies equal voltage dividers:

$$\frac{\dfrac{R_C R_D}{R_C+R_D}}{R_B+\dfrac{R_C R_D}{R_C+R_D}}=\frac{R_L}{R_A+R_L}=\frac{1}{2}.$$

Simplifying this equation yields

$$\frac{R_C R_D}{R_B R_C+R_B R_D+R_C R_D}=\frac{1}{2}. \quad (3)$$

You can solve **Eqs 2** and **3** simultaneously for the remaining unknowns R_B and R_C. First, simplify **Eq 2:**

$$A=\frac{1}{2}\left(\frac{R_D R_C+R_D R_B+R_C R_B}{R_C R_B}\right) \quad (4)$$

Next, rearrange **Eq 3** as

$$R_B R_C+R_B R_D=R_C R_D, \quad (5)$$

and substitute into **Eq 4:**

$$A=\frac{1}{2}\left(\frac{R_D R_C+R_C R_D}{R_C R_B}\right)=\frac{R_D}{R_B}.$$

Therefore,

$$R_B=\frac{R_D}{A}$$

is the second design equation.

For the last design equation, solve **Eq 5** for R_C:

$$R_C=\frac{R_B R_D}{R_D-R_B}.$$

Fig 3 shows an example of a circuit using 600Ω resistive loads and a gain of 2. The signal at IC_{1B}'s output measures only 2 to 3% of the signal-generator output. **EDN**

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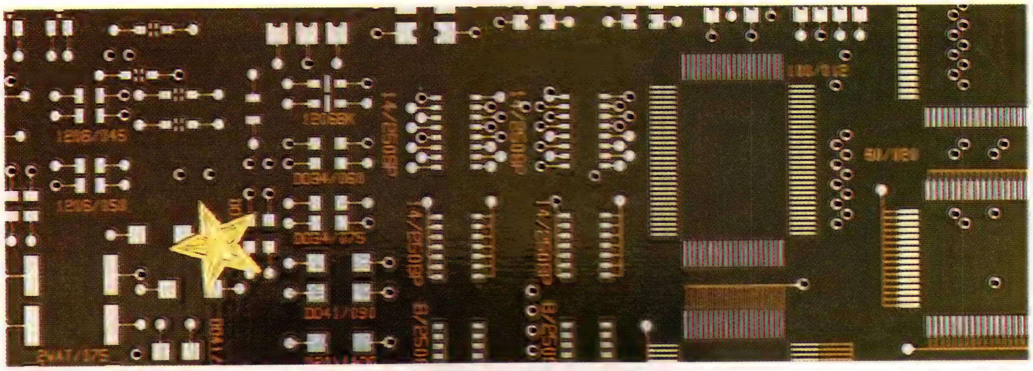
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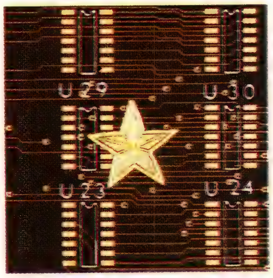
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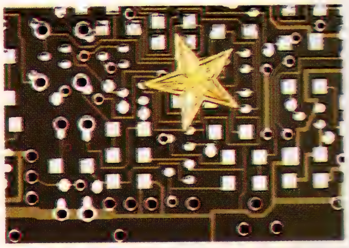
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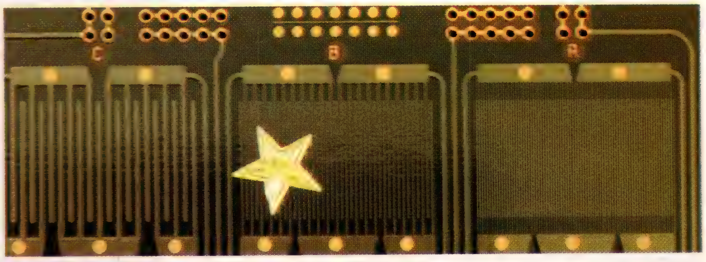
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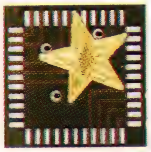
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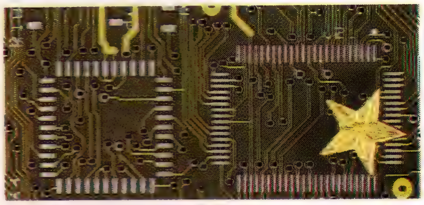
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(Job Title)
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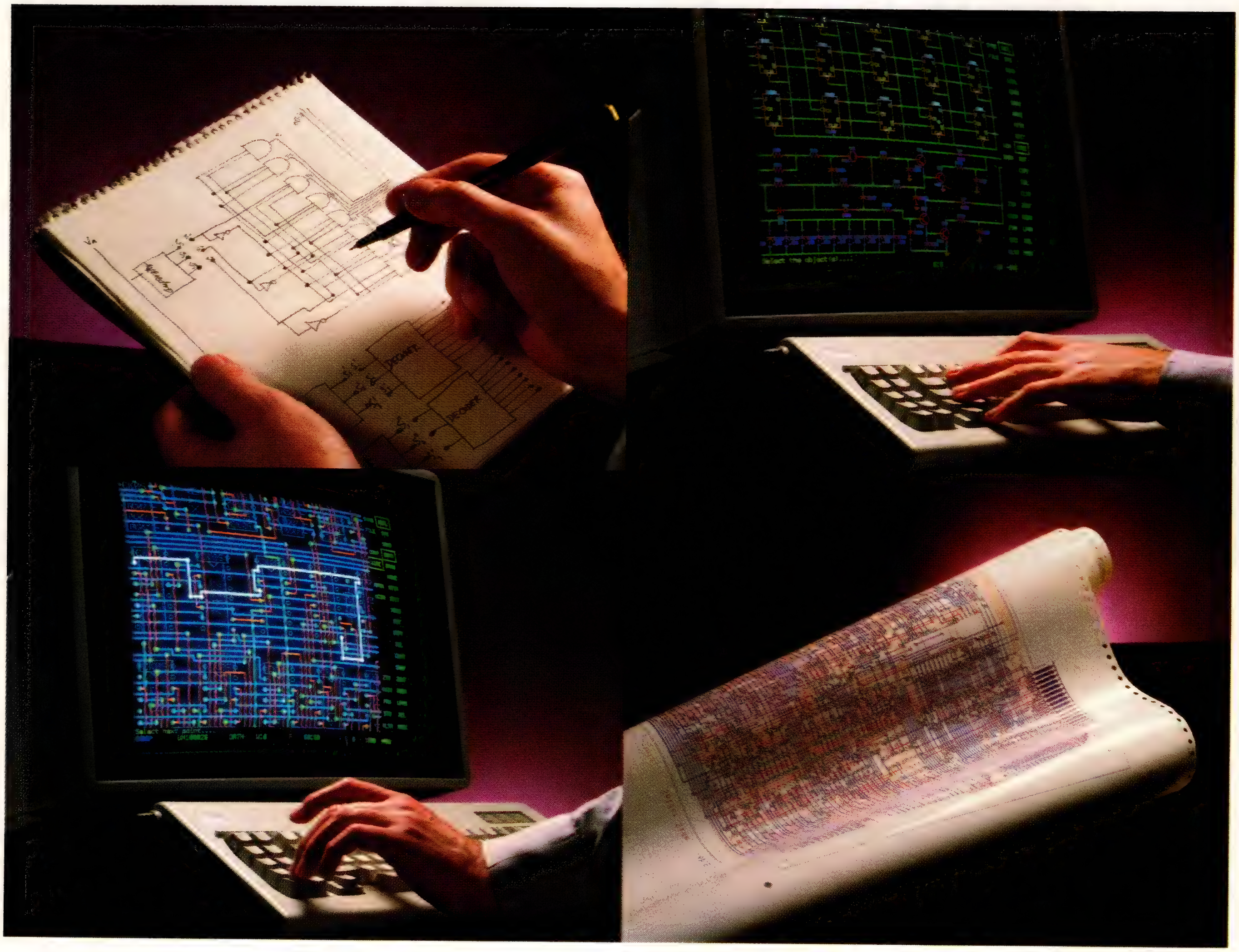
CIRCLE NO 119

Total Integration. From Concept to Prototype.



P-CAD's newest generation CAE/CAD design tools can take you all the way from concept to finished design on one system. That's why it's the Benchmark against which other design automation products are being judged.

FIRST, COMPARE FUNCTION.

P-CAD provides a true end-to-end PCB design solution. From interactive schematic capture, through automatic component placement and routing of trace interconnections and beyond, to paper tapes for NC drilling machines. All the way from concept to prototype on a single, integrated system.

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For more information, or a product demonstration, call P-CAD toll-free at (800) 628-8748 (in CA: (800) 523-5207; Internationally: (408) 971-1300). Or write: Personal CAD Systems Inc., 1290 Parkmoor Ave., San Jose, CA 95126. TELEX 3717199. (P-CAD products also available for rent or lease from US Instrument Rentals.)

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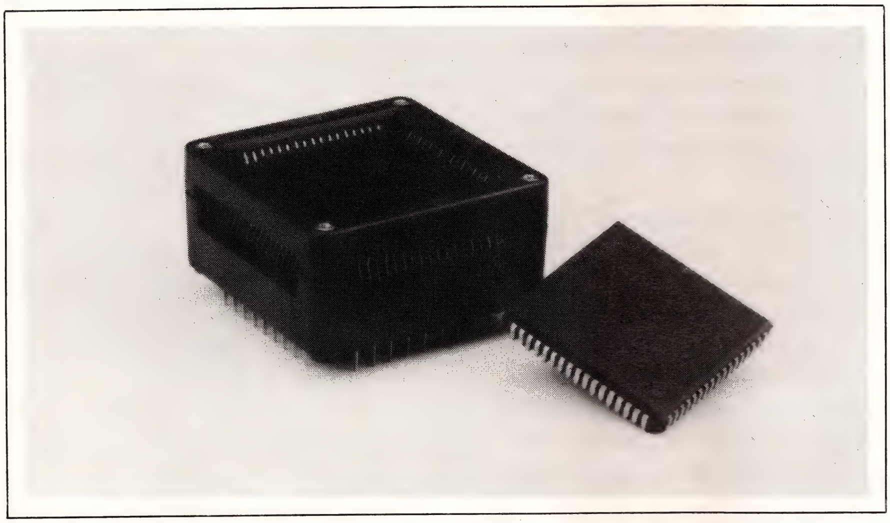
p-cad™

THE BENCHMARK

CIRCLE NO 170

NEW PRODUCTS

COMPONENTS & POWER SUPPLIES



BURN-IN SOCKET

- *Simple loading and unloading*
- *Contact made at the top and the sides of the leads*

Simple and quick loading of plastic leaded chip carriers (PLCCs) is a key feature of these 68-pin burn-in sockets. You accomplish a positive-contact load simply by pushing the PLCC device into the socket. An audible click signals reliable contact. A second push releases the device and automatically raises it above the socket edge to ease removal. When the device is locked in place, the socket makes contact at both the top and the sides of the leads. Other productivity advantages include quick visual polarization (because devices are tested right side up) and small size for increased board density. The socket has side and bottom vents that allow increased air flow around the device. $12.44 (1000).

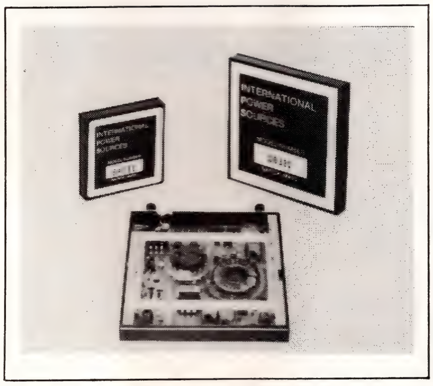
3M, Dept EP86-06, Box 2963, Austin, TX 78769. Phone (512) 834-6563.

Circle No 351

CONVERTERS

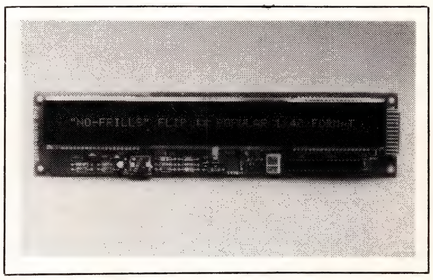
- *0.43-in. above-board profile*
- *500V dc input-to-output isolation*

SA and SB Series isolated, low-profile dc/dc converters employ hybrid technology and a 220-kHz switching frequency to achieve a $10W/in^3$ power density. The line of pc-board-mountable modules includes single- and multiple-output models that operate from a 48V dc nominal input and develop 5.1V/3A (SA) and 5.1V/4.5A, +12V/1A, and −12V/1A (SB) outputs. The SA and SB units come in 6-sided metal cases that measure 2×2×0.43 in. and 3×3×0.43 in., respectively. The converters feature 500V dc input-to-output isolation, 75% typ efficiency, and a 2,000,000-hour MTBF. The converters are convection cooled to operate over 0 to 60°C, and any output will provide as much as 50% of the total output power. $69 to $125 (OEM qty). Delivery, eight to 10 weeks ARO.



International Power Sources Inc, 10 Cochituate St, Natick, MA 01760. Phone (617) 651-1818. TWX 510-100-3630.

Circle No 352



DISPLAY MODULE

- *Displays 40-character line*
- *Characters are 0.2-in. high*

Model 3601-84-040 is a single-line, 40-character, 5×7-dot-matrix display. It measures 9.45×2.2×0.77 in. and features 0.2-in.-high characters. An onboard µP controller handles all scan, refresh, and data-I/O tasks, simplifying the interface to an 8-bit ASCII parallel-data bus. The module operates from 5V dc and displays the full 96-character ASCII set of upper- and lower-case letters, numbers, and symbols. The standard display color is blue-green, but a variety of color filters are available. $91 (100).

IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311. TLX 4720556.

Circle No 353

BACKUP BATTERIES

- *Primary batteries used with CMOS RAM for backup*
- *Below 37°C, batteries have a 20-year minimum shelf life*

The µPowerCell lithium-iodine batteries have a 2.8V output and are available in various capacities—1 Ahr (B-1000), 600 mAhr (B-600),

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Smarter Artwork

Three years ago, Wintek engineers created smARTWORK to reduce the time and tedium of laying out their own printed-circuit boards. Thousands of engineers have since discovered the ease of use and sophistication that makes smARTWORK the most popular PCB CAD software available. And thanks to them, smARTWORK keeps getting better.

smARTWORK transforms your IBM PC into a PCB CAD system

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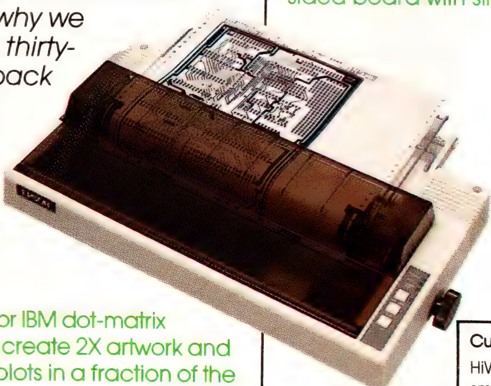

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- ☐ User-definable library
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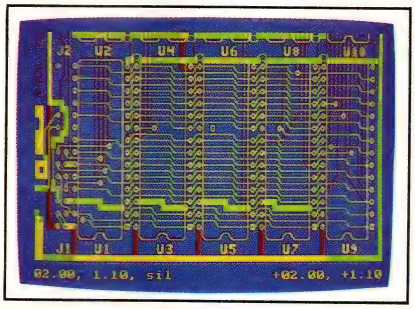
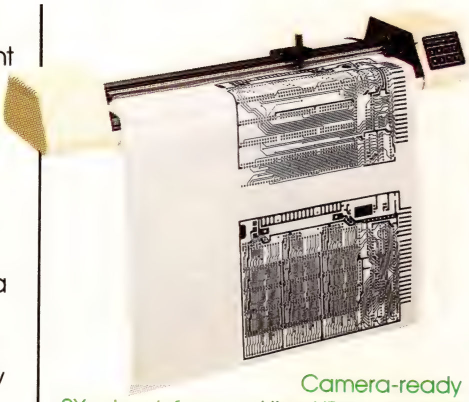


2″ by 4″ section of a 10″ by 16″ double-sided board with silkscreen layer

Current Versions

HiWIRE	V1.0r0
smARTWORK	V1.2r6



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- ☐ IBM PC, PC XT, or PC AT with 384K RAM, and DOS V2.0 or later
- ☐ IBM Color/Graphics Adapter with RGB color or B&W monitor
- ☐ IBM Graphics Printer or Epson FX/MX/RX-series printer, and/or
- ☐ Houston Instrument DMP-40, 41, 42, 51, 52, or Hewlett-Packard 7470, 7475, 7550, 7580, 7585, 7586 pen plotter
- ☐ Optional Microsoft Mouse

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1801 South St.
Lafayette, IN 47904
Telephone: (800) 742-6809
In Indiana: (317) 742-8428
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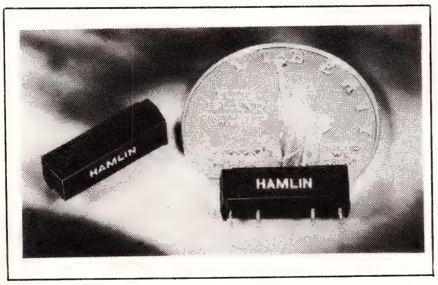
CIRCLE NO 121

and 400 mAhr (B-400). The configuration creates a layer of lithium iodine that acts as the electrolyte separator between the anode and the cathode. This separator is self-healing. The batteries have a 20-year-min shelf life at temperatures below 37°C. At temperatures above 50°C, you can use a float charge to extend battery life. Their useful operating range is −55 to +125°C. The wave-solderable batteries are packaged in a hermetically sealed, stainless-steel case that is welded and insulated with glass compression seals around the negative lead. A current-limiting, high internal impedance eliminates the danger of explosion due to reverse current, short circuit, or other electrical malfunctions. $3 to $6.

Catalyst Research Corp, 1421 Clarksview Rd, Baltimore, MD 21209. Phone (301) 296-7000.

Circle No 354



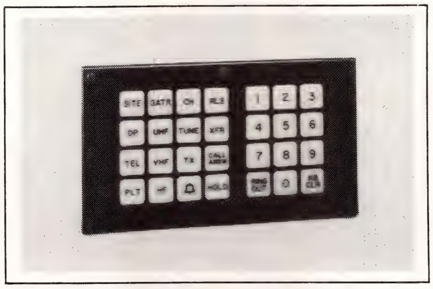
REED RELAY

- *Flame-retardant epoxy body*
- *2500V ac contact-to-coil dielectric standoff rating*

The Model HE3351A SIP reed relay features a dielectric standoff of 600V dc across the contacts and 2500V ac from the contacts to the coil. Housed in a flame-retardant molded epoxy case, the relay is supplied in Form 1A and is rated for 10W, 300V dc with a 0.5A max current-switching capability. Three coil voltages are standard—5, 12, and 24V dc. Measuring only 0.95×0.3×0.3 in., the relay is compatible with most automatic pc-board assembly and soldering equipment and is completely washable. $1.07 (5000) for a 5V coil-voltage model.

Hamlin Inc, Lake & Grove Sts, Lake Mills, WI 53551. Phone (414) 648-2361.

Circle No 355



KEYBOARD

- *Works in harsh environments*
- *Features a 5-bit binary output*

Originally designed for use in the space-shuttle program, this keyboard can operate in harsh environments. It features a parallel 5-bit binary output. The electrical interface is through a 9-pin D-type connector on the rear of the housing. The pushbutton, momentary keys feature an enhanced tactile feedback, with legends that are visible in any ambient lighting. Lamps for key illumination are field replaceable. An integral EMI-proof and splashproof gasket seals the keyboard at the panel interface. Internal seals make the keyboard splashproof. A variety of custom electrical interfaces and custom key legends are available on special order. $950 (100). Delivery, eight to 10 weeks ARO.

IEE Inc, Planar Product Div, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311.

Circle No 356

RESISTOR

- *Available in miniature SOT23 molded surface-mount package*
- *Standard tolerances of 1%*

The basic resistance element in the RSKM023 precision resistor is a nickel-chromium thin film deposited

REAL TIME HARDWARE

PC-PAL™ PROGRAMMER

The simple, fast and inexpensive way to program PALs in your PC or AT. Works with virtually all 20 and 24 pin devices from MMI, TI and NSC. Includes all the software needed to read, write and verify PALs. Works with JEDEC files and includes a compiler for MMI standard PAL types $395

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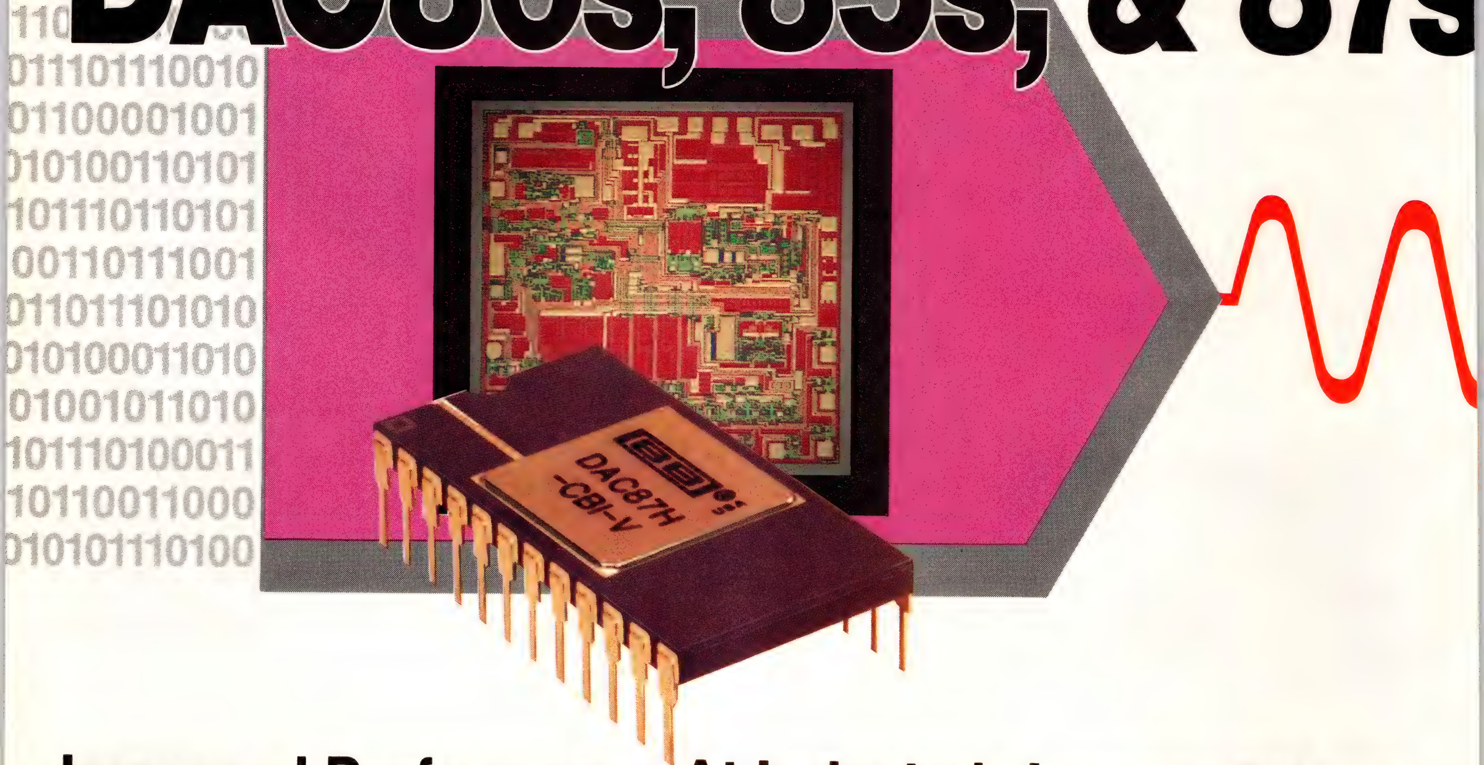
(617) 746-7341

CIRCLE NO 122

NEW MONOLITHIC DAC80s, 85s, & 87s



Improved Performance At Industry's Lowest Prices

We've sold millions of hybrid versions of these 12-bit D/A converters since we invented them over a decade ago. Our new monolithics are pin-compatible with existing DAC80/85/87 sockets, and they offer significant performance improvements—lower power dissipation, greater reliability, hermetic packaging—at very significant savings.

New DAC80/85/87 Features

- 345mW power dissipation
- 7.39 × 10^8hrs. MTTF (@25°C)
- TTL-, CMOS-compatible inputs
- Settling time (±0.01%FSR): 3μs (V_{OUT}), 300ns (I_{OUT})
- ±1/2LSB max nonlinearity and guaranteed monotonicity:
  0/+70°C DAC80, DAC80P
  −25/+85°C DAC85H
  −55/+125°C DAC87H
- 24-pin hermetic or molded plastic DIP

Evaluation Samples Ready Now

Your sales representative is ready with your DAC80/85H/87H evaluation samples and data sheets. Call soon.

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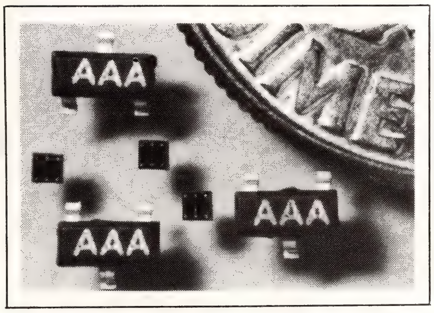
Improving Data Conversion Productivity

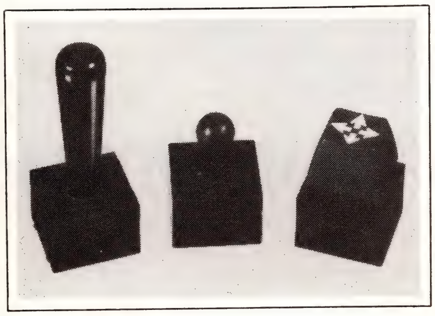
CIRCLE NO 123



on a silicon microchip. Housed in a miniature SOT23 molded surface-mount package, it is available in values ranging from 250Ω to 250 kΩ. The resistance tolerance specs at 1% standard, and the temperature coefficient of resistance equals 25 ppm/°C max over the full military temperature range. Load-life stability at 125°C measures 750 ppm max. Additional specifications include a 125-mW power rating, a −35-dB max noise rating, and a 1-nsec max rise time. $1 (OEM qty). Delivery, stock to eight weeks ARO.

Ultronix Inc, Box 1090, Grand Junction, CO 81502. Phone (303) 242-0810.

Circle No 357



SWITCHES

- *Rated to switch 250 mA*
- *Make-before-break action*

Series 4 digital joystick switches are 0.85 in. square and have a behind-the-panel depth of 0.55 in. A cross-type contact system is suspended on a common terminal. Contact is made in one of four quadrants, depending on the direction of the actuating force. The contact action is a make-before-break action that allows the adjacent quadrant positions to contact the common terminal as the actuator is moved from one adjacent position to the next. Although rated to make and break 250 mA at 115V ac, the switches work well at logic-level currents and voltages, according to the manufacturer. $4.25 (100).

Grayhill Inc, Box 10373, La Grange, IL 60525. Phone (312) 354-1040.

Circle No 358

DIP SWITCHES

- *Fully compatible with standard automatic-handling equipment*
- *Sealed to withstand automatic-solder and cleaning processes*

Machine-insertable DIP switches in the 51D Series are fully compatible with standard automatic-handling equipment. They are fully sealed to withstand automatic solder and cleaning processes. The switches are available in 2- through 10-position spst configurations. Contacts are gold over nickel to ensure low contact resistance, and they are rated to switch 5V/100 mA loads. Pins are spaced on 0.1-in. centers. The switch actuators are recessed to prevent accidental actuation. Insulator and cover materials (glass-filled, flame-retardant thermoplastic) carry a 94V-0 UL rating. Sturdy 0.02×0.146-in. terminals eliminate automatic-insertion problems and ensure proper alignment. $0.72 (5000) for an 8-position model. Delivery, stock to six weeks ARO.

JAE Electronics Inc, 1901-A E Carnegie Ave, Santa Ana, CA 92705. Phone (800) 523-7278; in CA and AK, (714) 250-8770.

Circle No 359

SUPPRESSORS

- *Housed in low-profile surface-mount packages*
- *Operate over a −65 to +150°C range*

SMC Series transient voltage suppressors are housed in low-profile surface-mount packages. They feature 1500W peak pulse-power dissi-

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For the IBM PC, XT and compatibles

A2D-160™ The fastest 12 bit A/D converter!
166,000 samples per second
Includes Pseudo Random Noise Generator/DAC. For the IBM-PC, XT and AT. $1,295
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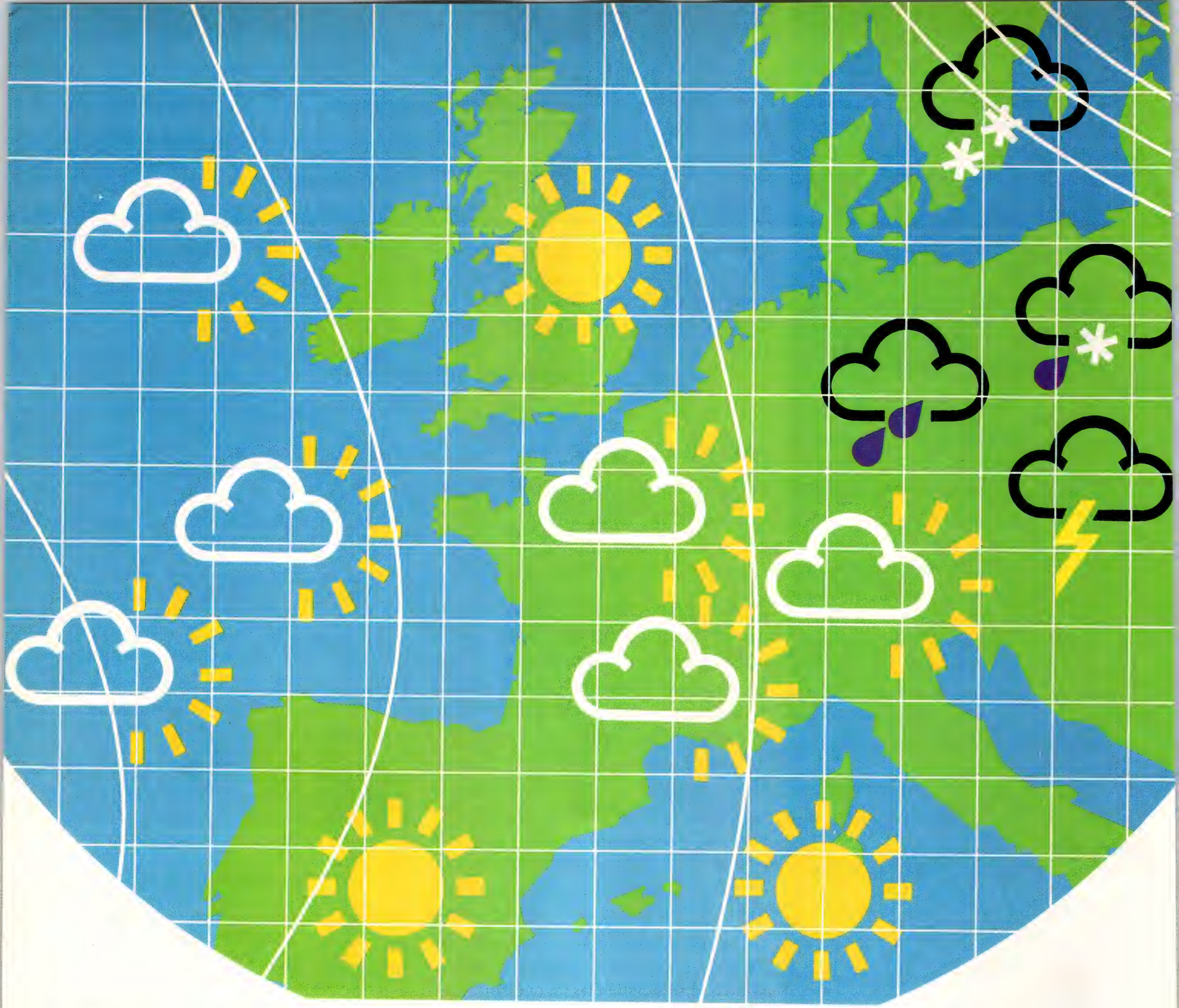
CIRCLE NO 161



DS is a match for any fast changing climate.

With 1ns gate delays and system speeds to 100MHz, the new Ferranti 'DS' range of ULAs* handles rapidly changing data under the most demanding conditions.

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☐ average gate power 100μW at 60MHz
☐ 48mA output drivers on every I/O cell
☐ low output delays driving high capacitance loads
☐ digital, I/O and linear macros

It all adds up to one of the most advanced high-speed low-power ASIC product ranges you'll find under the sun.

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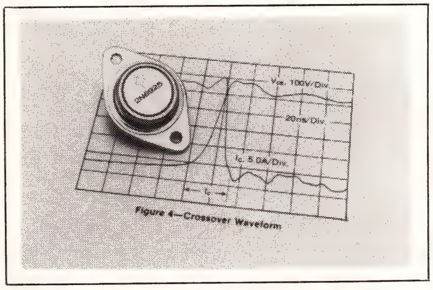
☐ Ferranti Wheelock Microelectronics, Aberdeen, Hong Kong, Tel: (5)-538298-9 ☐ Ferranti Interdesign Inc. USA, California, Tel: (408)-438-2900.

CIRCLE NO 124

pation for a 1-msec pulse, and a threshold response time of 1×10^{-12} sec. Reverse-current leakage specs at 5 μA, and the operating and storage temperature are both −65 to +150°C. The units are available with breakdown voltages ranging from 5 to 220V. Two lead configurations are available: gull-wing and J. The units are compatible with pick-and-place equipment. They are packaged for shipment to meet EIA spec RS-481 and enclosed in 16-mm carrier tape. $1.07 (5000).

General Semiconductor Industries Inc, Box 3078, Tempe, AZ 85281. Phone (602) 968-3101.

Circle No 360



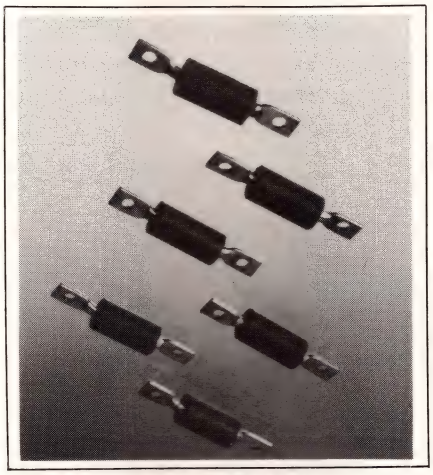
POWER TRANSISTORS

- *Spec a 25A collector current*
- *Switch 500V at 50A inductive loads with no degradation*

The 2N6924 and 2N6925 npn switching transistors offer a 35-nsec crossover time, guaranteed switching performance at 100°C, and V_{CEO} specs of 400 and 450V, respectively. The continuous collector current specs at 35A. The typical $V_{CE(SAT)}$ is just 0.8V at 25A and 100°C. Both units will switch 500V/50A inductive loads with no degradation in performance. When the units are switching interactive loads at 25A and 25°C, the typical rise time equals 20 nsec, and the fall time equals 15 nsec. The devices operate over −65 to +200°C. 2N6924, $17.50; 2N6925, $19.50 (100).

General Semiconductor Industries Inc, Box 3078, Tempe, AZ 85281. Phone (602) 968-3101. TWX 910-950-1942.

Circle No 361



POWER RESISTORS

- *Achieve stability of 3% per 1000 hours at rated power*
- *Are available in noninductively wound versions*

PM Series precision power resistors offer power-dissipation ratings of 3.5, 5.5, 8, 10, and 11W, and they achieve long-term stability of 3% per 1000 hours at rated power. They specify a TC of better than 50 ppm/°C. A silicone molding provides insulation for the resistors' bodies. The devices are available in ohmic ranges from 0.051 to 10, 27, 68, 100, and 100,000Ω, with corresponding voltage ratings of 100, 160, 200, 500, and 750V. Standard tolerances are ±5, ±2, and ±1%; you can order resistors with a ±0.5% tolerance. For a restricted range of ohmic values, you can also specify that the resistors be noninductively wound. Approximately £0.21 (1000).

CGS Resistance Company Ltd, Marsh Lane, Lymington, Hants SO41 9YQ, UK. Phone (0590) 75255. TLX 47691.

Circle No 362

ENCODERS

- *Accuracy of one part in 3600*
- *Accommodate harsh environments*

DDS90-10 scalable differential encoders provide the absolute difference between two rotating shafts with accuracies of one part in 3600.

REAL TIME SERVICE

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An adjustable oscillator lets you increase your AT's 80286 speed in .5 MHz increments. Includes a 10 or 12 MHz 80287 clock and a system reset button.

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8087 Upgrades

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80287-3	5 MHz	**$179**
80287-6	6 MHz	**$199**
80287-8	8 MHz	**$259**
80287-10	10 MHz	**$395**
NEC V20-8	8 MHz	**$16**
NEC V30-10	10 MHz	**$30**
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256K RAM set	150 ns	**$27**
256K RAM set	120 ns	**$39**
128K RAM set	PC AT	**$49**

8087 Software

87 BASIC™ A patch to the IBM Basic or MS QuickBASIC compiler that provides fast, USER TRANSPARENT 8087 support...... **$150**

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87 Verify™ For users that have to be absolutely sure of their results! This background task periodically performs an 8087 accuracy and stress test..................... **$49**

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P.O. Box 79
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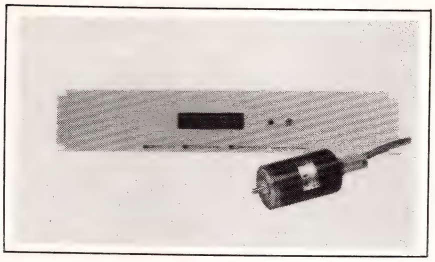
CIRCLE NO 200



They are well suited for harsh environments and can convert any two shaft inputs to BCD or binary information. In addition, 3-, 4-, or 5-digit, 0.5-in. LED displays read out the angle. The encoders employ a resolver for the shaft transducer. An offset adjustment allows you to set the zero point, and a variety of output scale factors, including pounds, feet, and meters, are available. Data outputs are TTL compatible. Data-transfer and data-hold lines simplify the interface to a computer. The basic update rate is 2.5 msec. Operation spans 0 to 70°C or −55 to +85°C. NEMA 12, waterproof, and explosion-proof transducer housings are optional. $595/axis.

Computer Conversions Corp, 6 Dunton Ct, East Northport, NY 11731. Phone (516) 261-3300. TWX 510-226-0448.

Circle No 363

CAPACITORS

- *Carry 94V-0 UL rating*
- *Dissipation factor is 0.05%*

The CMPP Series of capacitors is constructed of a zinc-metallized polypropylene dielectric that's both self-healing and nonpolar. The capacitors feature a glass-fiber-reinforced box-type plastic case that is flame retardant to UL spec 94V-0. The typical dissipation factor is 0.05% at 60 Hz. Capacitance values range from 0.4 to 34 µF, with voltage ratings of 220, 250, 440 and 550V ac. Standard tolerances are ±10% (K), ±6% (Y), +10%/−5% (U), and +20%/−5% (W). For a 5-µF, ±10%, 250V ac unit, $1.20 (10,000). Delivery, eight to 10 weeks ARO.

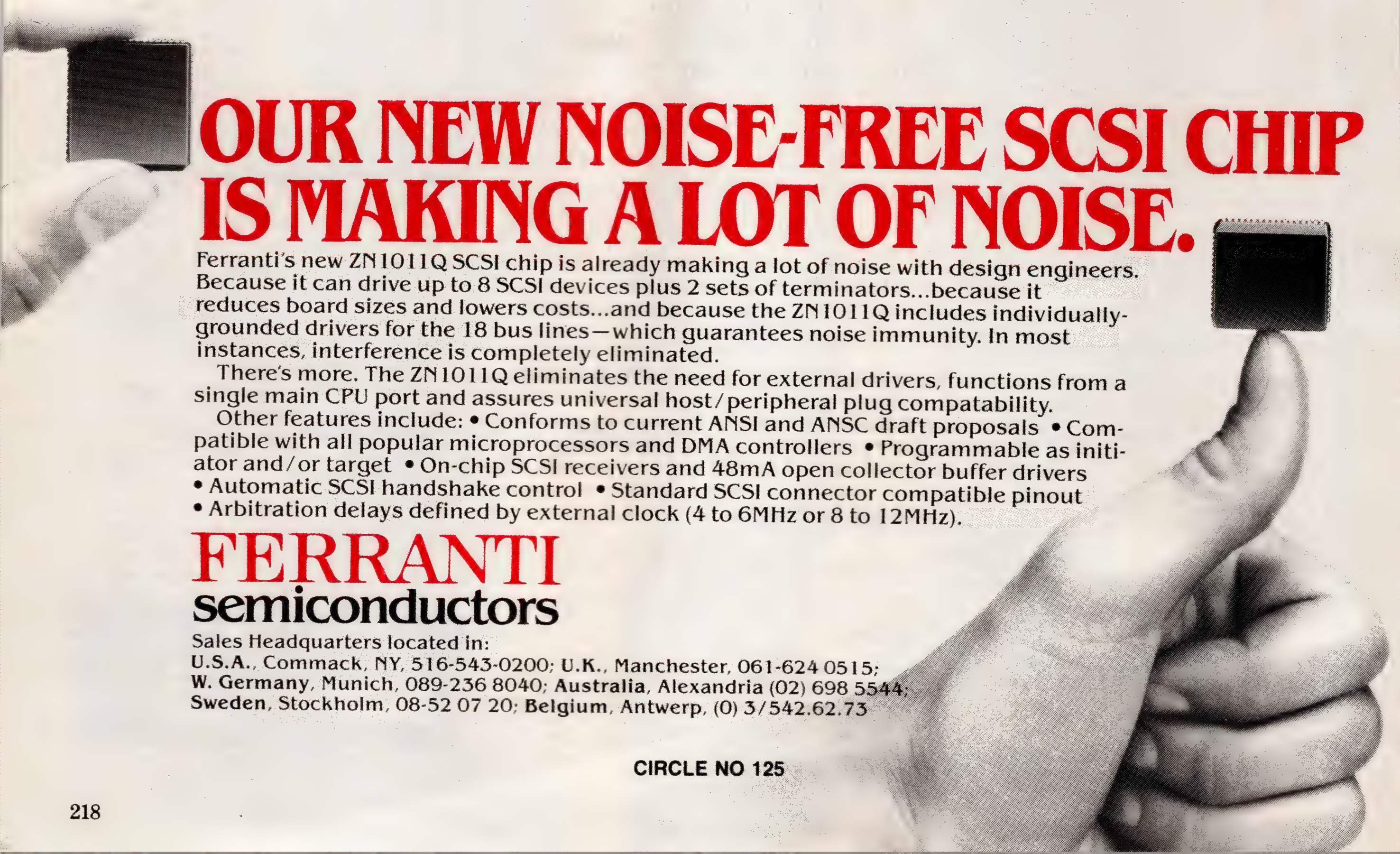
American Shizuki Corp, 21541 Blythe St, Canoga Park, CA 91304. Phone (818) 710-8555. TLX 662633.

Circle No 364

DC/DC CONVERTERS

- *Provide input to output isolation of 500V*
- *Calculated MTBF is more than 270 years*

Scarab pc-board-mountable, isolated dc/dc converters include 15, 25, and 30W versions operating from 24 or 48V dc inputs. The 15W versions, which are single-output converters, provide a 5.1, 12, or 15V output. The 25W versions (triple-output converters) provide +5.1V and −5.1V outputs and either ±12, ±15, or +12V outputs. The 30W



OUR NEW NOISE-FREE SCSI CHIP IS MAKING A LOT OF NOISE.

Ferranti's new ZN1011Q SCSI chip is already making a lot of noise with design engineers. Because it can drive up to 8 SCSI devices plus 2 sets of terminators...because it reduces board sizes and lowers costs...and because the ZN1011Q includes individually-grounded drivers for the 18 bus lines—which guarantees noise immunity. In most instances, interference is completely eliminated.

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Other features include: • Conforms to current ANSI and ANSC draft proposals • Compatible with all popular microprocessors and DMA controllers • Programmable as initiator and/or target • On-chip SCSI receivers and 48mA open collector buffer drivers • Automatic SCSI handshake control • Standard SCSI connector compatible pinout • Arbitration delays defined by external clock (4 to 6MHz or 8 to 12MHz).

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semiconductors

Sales Headquarters located in:
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CIRCLE NO 125

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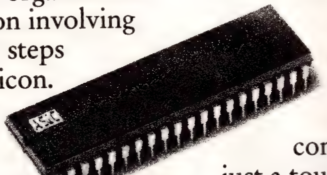

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AC and DC Inputs

For 5x8x11 "slot" switching power supplies from 600 to 1800 Watts, the Qualidyne Case 10 is all you need to know. MTBF of 50,000 hours. Single or multiple (up to 5) fully regulated outputs from 2 to 48 VDC. Precision paralleling for N+1 redundancy. AC and DC input voltages. Safety listings from UL, CSA and TUV. Compliance with IEC 380 & VDE 0806. FCC 20780 Class A filtering. Nothing fancy, just reliable slot power—period.

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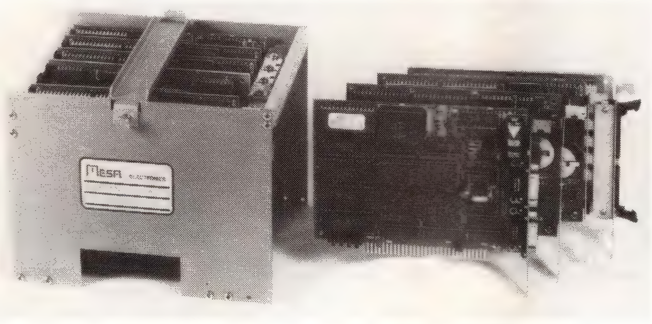

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CIRCLE NO 128

versions are available as either single-output converters providing 5.1, 12, or 15V, or as dual-output converters providing ±12 or ±15V. All 25 and 30W converters feature a remote-shutdown input. Converters with nominal 24V inputs operate over a 19 to 35V input voltage range; 48V versions operate over a 35 to 63V input voltage range. Combined input and output regulation over the full operating-temperature range amounts to ±2% for the main output, ±3% for fully regulated secondary outputs, and +7 to −19% for semiregulated secondary outputs. From £40 (1000).

STC Components Ltd, Power Sources Div, Edinburgh Way, Harlow, Essex CM20 2DE, UK. Phone (0279) 26811. TLX 818746.

Circle No 365

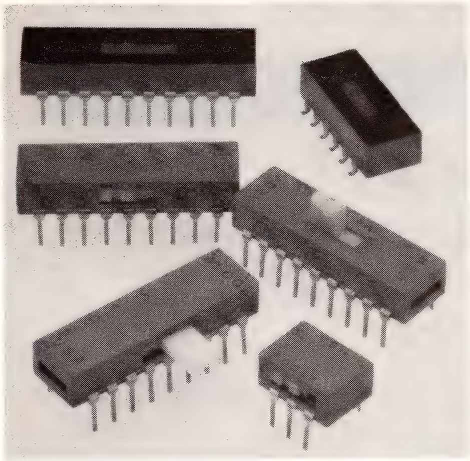
POWER SUPPLIES

- *User-selectable input sections have EMI filters*
- *Soft start and current limiting for circuit protection*

Enclosed in a 6×4.25×1.45-in. package, convection-cooled LPS Series switching power supplies feature 100W output ratings. To achieve this power rating, the supplies employ an 80-kHz MOSFET converter that has been designed to meet VDE0806, UL478, and CSA22.2 safety specs. Input sections have onboard EMI filters and accommodate either 110 or 220V (user programmable). Standard features include soft start and current limiting for circuit protection. The units have a 20-msec holdup time and ±0.5% total regulation on 5, 12, 15, and 24V outputs. A 2-stage output filter limits output ripple and noise to 1% p-p. Single-output units, $97.50 (100).

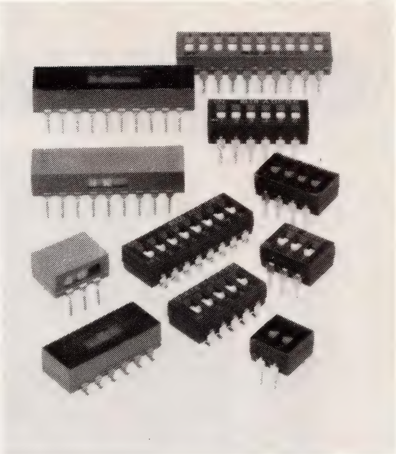
Integrated Power Designs Inc, 9 Princess Rd, Suite C, Lawrenceville, NJ 08648. Phone (609) 896-2122.

Circle No 366



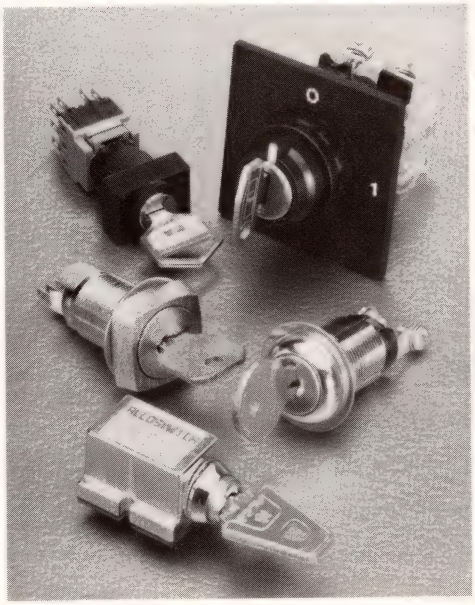
AUTO INSERTABLE SWITCHES

Alcoswitch has the first auto-insertable/surface mount (process compatible) switches on the market today. Their construction allows them to be emersion cleaned in either aqueous or solvent processes and they can withstand vapor phase reflow and wave soldering techniques. The ASE/F Series is a Dip package slide switch available with one, two, four or six pole versions. The AD Series are 2 through 10 position dip switches with flush, extended or piano style actuators. These Dips are also available with built-in thick film resistor networks (AR Series) or diode network either cathode or anode common (AA/C or RR Series). Call today for applications help or request your FREE catalog. (617)685-4371. ALCOSWITCH, 1551 Osgood Street, North Andover MA 01845.



ASE/F SLIDE SWITCHES

The ASE/F slide switches are available in one, two, four or six pole versions. There are two standard types: ASF- Dip package with flush actuators allows auto insertion on standard IC equipment. Standard tape seal and closed case construction provide process seal. ASE - extended actuator open ended case allows washout after process cleaning. Industry standard .100 x .300 pin spacing. The new surface mount switches are designed specifically to withstand the elevated temperatures generated by vapor phase reflow or wave soldering processes. Termination options include PC or surface mount "L" pad and reverse "L" terminals. Call today for applications help or request your FREE catalog. (617) 685-4371. ALCOSWITCH 1551 Osgood Street, North Andover MA 01845.



KEYLOCK SWITCHES

ALCOSWITCH offers attractive and functional keylock switches in low, medium and high security types. Rotary selector, logic level (0.4 VA), and power (6A up to 600 volt) models are available. Programmed output using up to 31 keys, round or rectangular bezels, 2,3 or 10 position, maintained or momentary, single or multipole with U.L./CSA approval. Call today for applications help or request your FREE catalog. (617) 685-4371. ALCOSWITCH, 1551 Osgood Street, North Andover MA 01845.

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Many interesting features and options.

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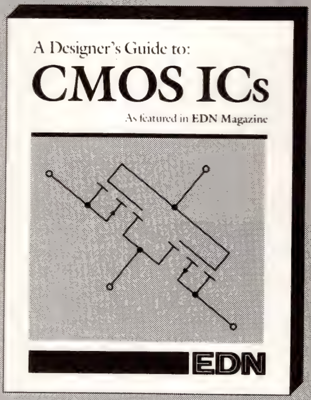

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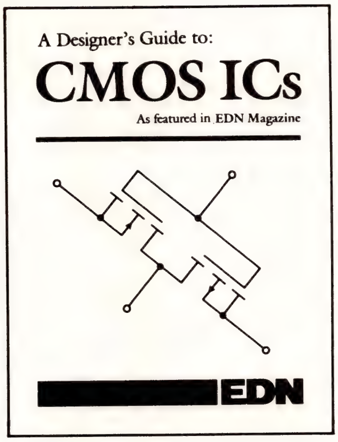
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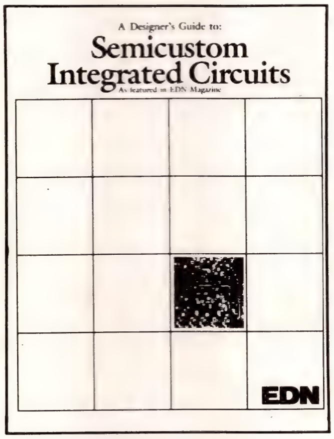
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As featured in EDN Magazine
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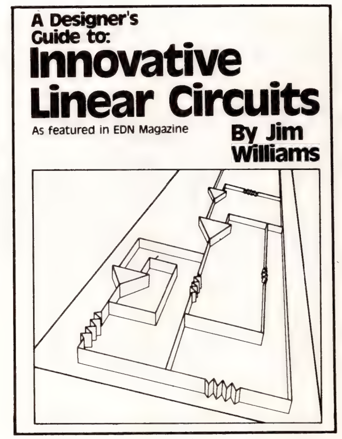
Learn how to design a semicustom IC with *A Designer's Guide to Semicustom Integrated Circuits.* Based on EDN's own design experience, this nine-chapter booklet outlines the complete procedure used to design, fabricate, and test EDN 1, a chip with a 1200 equivalent-gate complexity. You'll not only learn the steps to take when creating ICs, but also the design/cost analyses and vendor-interface methods that lead to successful semicustom chips.


A Designer's Guide to:
Innovative Linear Circuits
As featured in EDN Magazine
By Jim Williams

A Designer's Guide to Innovative Linear Circuits

As exciting as digital technology is, you still need analog circuitry to operate on signals from real-world sources. Now, EDN is offering a wealth of analog design information in *A Designer's Guide to Innovative Linear Circuits.* This 186-page collection of articles was developed by Jim Williams, one of America's foremost linear-circuit designers. It includes practical and efficient ways to use op amps, comparators, data converters, and other analog ICs, and discusses the theories behind all the design techniques presented.

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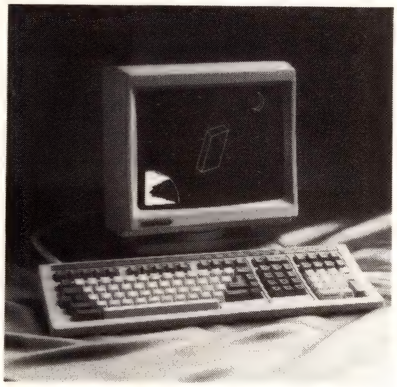
NEW PRODUCTS

COMPUTERS & PERIPHERALS



TERMINALS

- *Compatible with DEC VT220 units*
- *Feature black characters on a white background*

Foresight Edition alphanumeric and graphics terminals offer black characters on an overscanned, reverse-video, soft-white background. The Foresight 4520 emulates the DEC VT220; the 4525 is a VT220-compatible terminal that can be upgraded to include Tektronix 4010/4014 and Regis graphics capability. The 4560 combines DEC VT220 emulation with Tektronix 4010/4014 graphics compatibility. Each of the terminals provides 500 scan lines, instead of the 240 commonly found in VT220-compatible terminals. The Foresight models use a 20×20-dot character cell in which characters are formed from a 15×18-dot matrix. The terminals also feature multiple pages of screen memory, user-programmable compose and function keys, and alternate keyboards. 4520, $695; 4525, $795; 4560, $1295.

Micro-Term Inc, 512 Rudder Rd, St Louis, MO 63026. Phone (314) 343-6515. TWX 910-760-1662.

Circle No 368

OPTICAL-DISK UNIT

- *Offers as much as 40G bytes of random-access storage*
- *Multiplatter disk carrier*

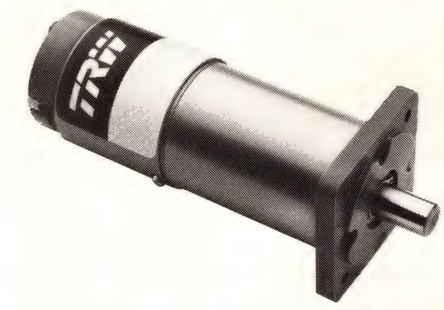
The Optical-Disk Storage and Retrieval Unit (ODSR) provides as much as 40G bytes of random-access storage on read-only optical drives. It can incorporate one or two LaserDrive 1250 WORM drives and a 16- or 20-crypt tower for the manufacturer's LaserDrive media. The ODSR uses several interfaces. The LaserDrive 1250 works with a SCSI or ISI (intelligent systems interface) bus. An RS-232C interface acts as the control interface, which you use to send all motion commands to the ODSR. The Laserdrive 1250 also performs data-I/O functions on the drive interface, leaving the RS-232C port free to

Text continued on pg 235

WHO DO YOU THINK

makes 16K and 32K PROMS that are 20% faster than anyone else's?

(See page 182)



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TRW

Motor Division
TRW Electronic
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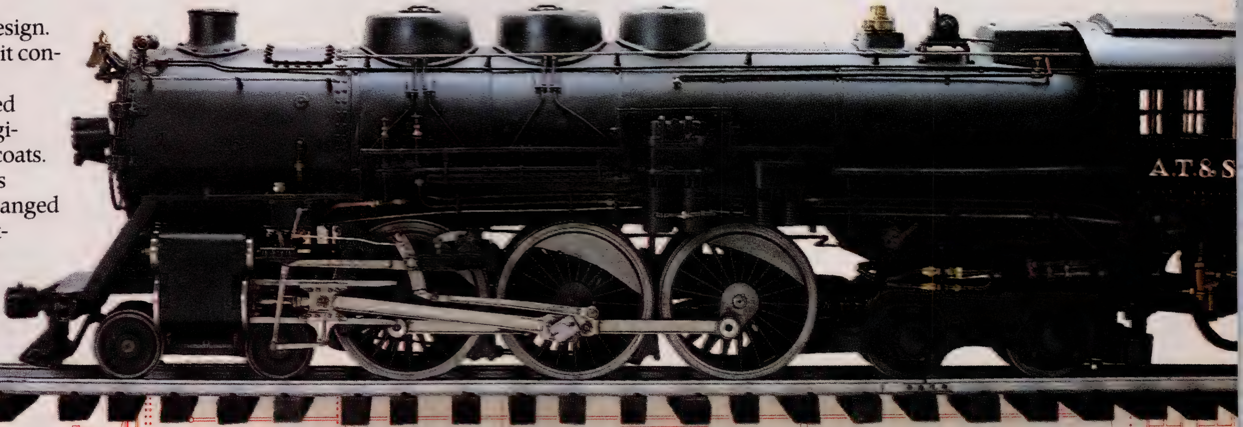
CIRCLE NO 132

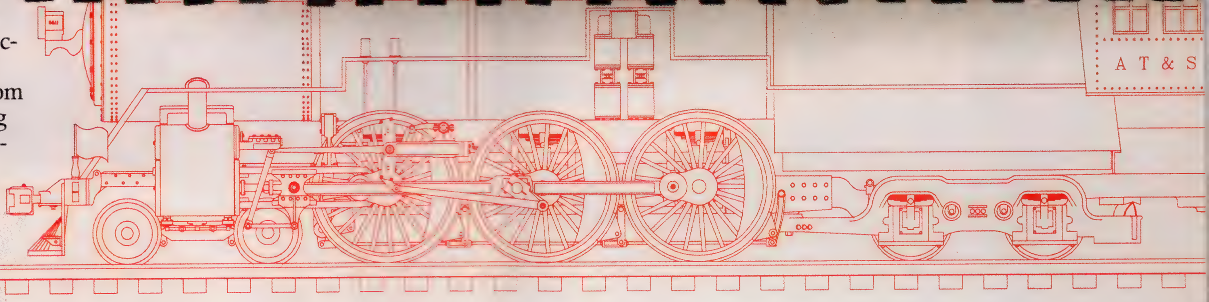
Put yourself on the right track with CAD.



Computer-aided design.

Until recently, it conjured up images of massive, room-sized computers and engineers in white lab coats.

But a few years ago, AutoCAD® changed all that. With a software package that turned the personal computer on your desk into an easy-to-use electronic drawing board.



For everything from PC boards to shopping centers. Tooling to topographical plans. Technical illustrations. Facilities layouts.

Even #4-6-4 Hudson model railroad trains.

Now AutoCAD is even better.

Introducing AutoCAD 2.5

Of course, the newest version of AutoCAD still has all the features that made the original the industry standard. Accuracy, Power, and Versatility.

But now, there are improvements all down the line.

For example, AutoCAD performs most PAN and ZOOM operations five to ten times faster than the previous version. So design and redesign are faster than ever.

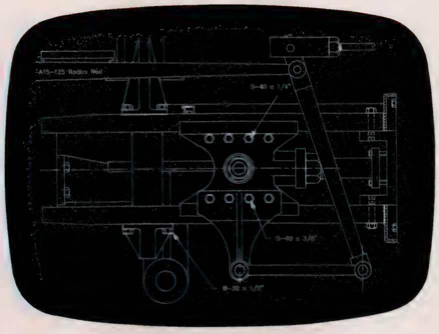
There is also a wealth of new commands for creating ellipses, doughnuts, and polygons. And new editing commands that let you STRETCH, TRIM, EXTEND, ROTATE, SCALE, and EXPLODE objects.

The result? A powerful electronic drawing tool that lets you concentrate on the drawing, and not on the electronics.

Feel Comfortable at the Controls

Never used a computer before? AutoCAD's easy-to-use menus guide you from action to action. You can even create your own menus. And use an on-line "HELP" command if you get stuck.

Drawings Courtesy of Little Engines, Inc.



Save hours of drafting time. Draw frequently used diagrams just once and re-enter where needed.

What if you have second thoughts, or make a mistake? AutoCAD's new, sweeping UNDO capability lets you erase what you've done—so you have total freedom to draw and experiment.

There are also enhanced customization features. Support for over 30 different microcomputers (as well as several 32-bit UNIX-based systems). Even support for the new IGES standard, to let you easily and accurately translate drawings between AutoCAD and most other CAD systems.

All of which combine to make the new AutoCAD fit more neatly and comfortably than ever into the way you're used to working.

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Call us too if you want the location and telephone number of your nearest AutoCAD Authorized Training Center.

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CIRCLE NO 133

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Bring 32 bit 80386 power to your existing software. Or upgrade your 68000 designs to 25 MHz speeds. Both with no-wait-states. You now have the choice between the two most powerful 32 bit micros on the industry leading VMEbus. Check the best product for your application.

Force 32 bit CPU Availability

	CPU-20	CPU-21	CPU-24	CPU-25	CPU-386A	CPU-386B
Processor	68020*	68020*	68020*	68020*	80386*	80386*
Available frequencies	12.5/16.7/20/25	12.5/16.7/20/25	12.5/16.7/20	12.5/16.7/20	12/16/20	12/16/20
Number of wait states	0	0	1	1	0 (1 at 20 MHz)	
FPU	no	yes	no	yes	no	yes
MMU	no	no	yes	yes	yes	yes
Memory capacity	0.5 to 4 MB SRAM		0.5 to 4 MB SRAM		2 to 8 MB DRAM	
EPROM capacity	512 KB	512 KB	64 KB	64 KB	256 KB	256 KB
Serial I/O channels	3	3	3	3	3	3

68020 ?

VME

- Processor Boards
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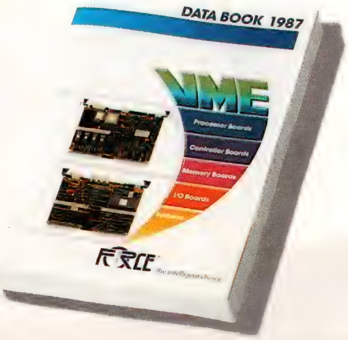

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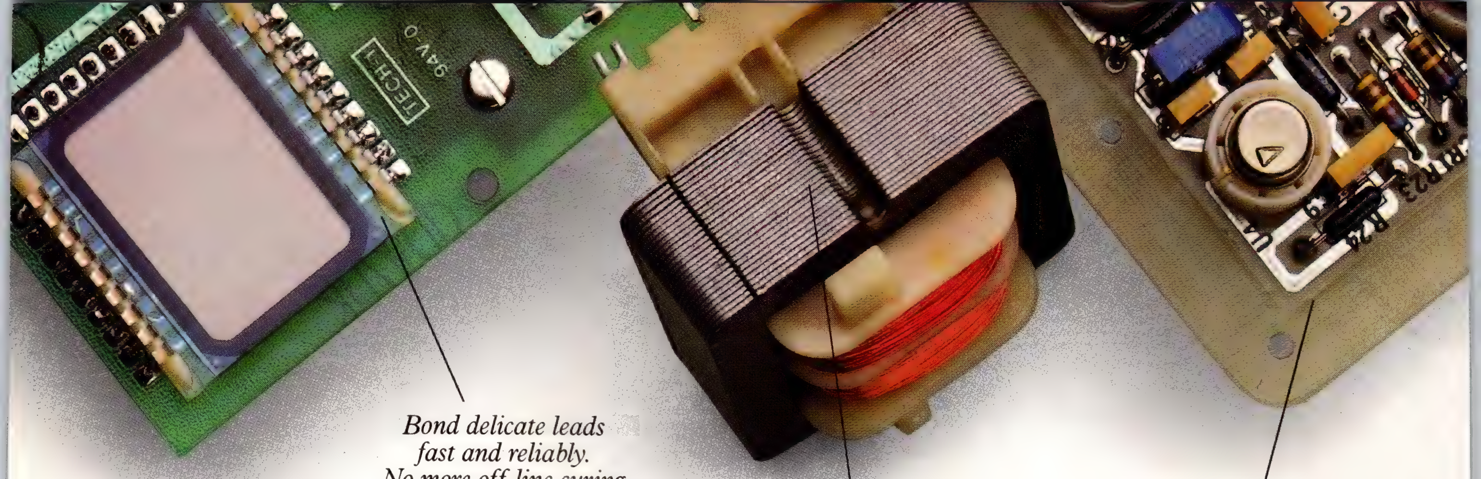

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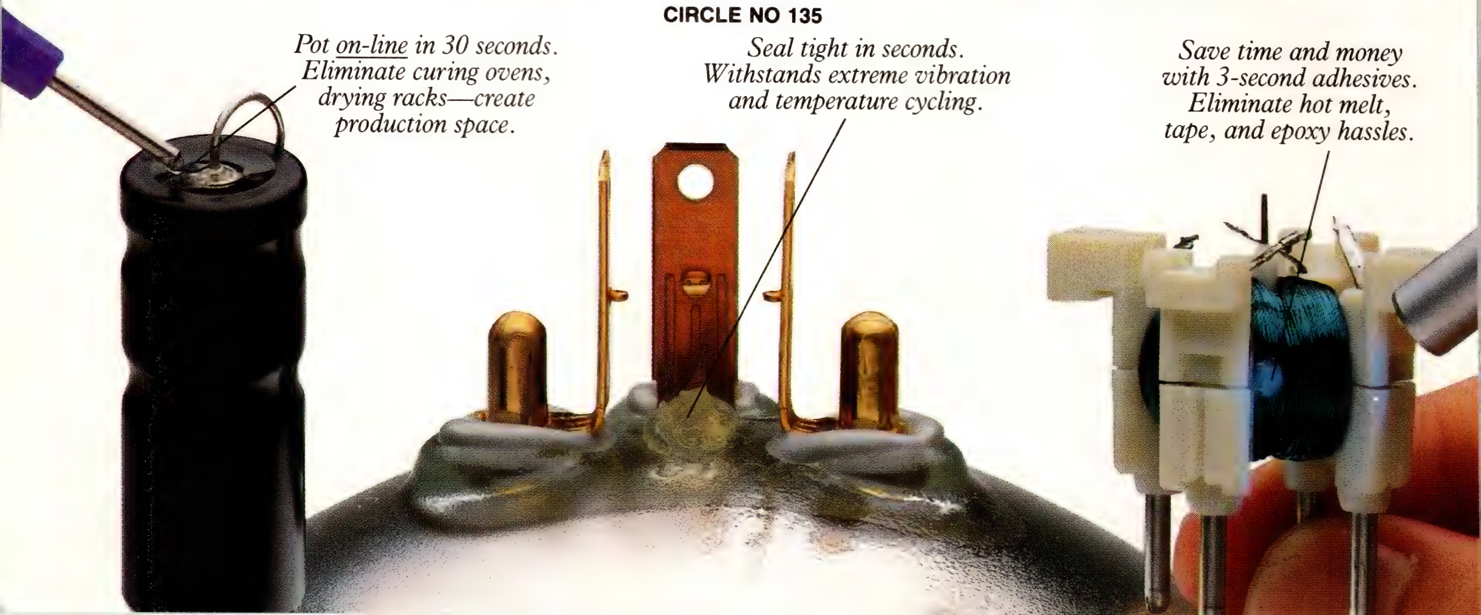
CIRCLE NO 135



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receive cartridge-transport commands concurrently. The ODSR includes a built-in power supply, dual buffers for queued operation, an I/O station for externally loading and unloading cartridges, self-diagnostics, and error-detection and -correction capabilities. $17,000 (OEM qty).

Laser Magnetic Storage International, 4425 ArrowsWest Dr, Colorado Springs, CO 80907. Phone (303) 593-4269.

Circle No 369

SCANNER

- *Image scanner works with IBM/PC and compatibles*
- *Converts hard-copy images to bit-image data*

The Image Scanner Option Kit for Epson's EX-800, EX-1000, and LQ-2500 dot-matrix printers works with IBM PCs and compatibles equipped with the EGA (Enhanced Graphics Adapter), CGA (Color Graphics Adapter), or Hercules display adapters. The scanner converts hard-copy images such as photographs, logos, maps, clip art, and other textual or graphical documents into bit-image data. Using the Inset software package, you can manipulate and integrate the images with word-processing and spreadsheet packages. The kit includes the scanner mechanism, an identity cartridge, a diskette containing the company's scanner utility and Inset software, and a user's manual. When used with the LQ-2500 printer, the scanner offers a resolution of 180×180 dpi; when used with the EX Series printers, it offers 144×144-dpi resolution. $300.

Epson America, Computer Products Div, 2780 Lomita Blvd, Torrance, CA 90505. Phone (800) 421-5426; in CA, (213) 539-9140.

Circle No 370

FIR-FILTER DESIGN

- *Uses one slot in IBM PC*
- *Menu-driven software for development included*

The EVK-128 filter-design system is a development tool for FIR (finite impulse response) filters. It occupies one slot in an IBM PC or compatible computer. The menu-driven interface includes coefficient calculations, time and frequency calculations, and plotting capabilities, as

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Memory Boom by Mid-1990

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INSIDE

DSP Board Fits IBM PC

GE/Intersil's EVK 128 combines A/D conversion and FIR filtering

Power MOSFET Makers Boost Electrical Specs

Manufacturers improve electrical characteristics and offer a host of package types

HOT NEWS OF PRODUCTS, TECHNOLOGY, AND CAREERS

Who makes LED Illuminators

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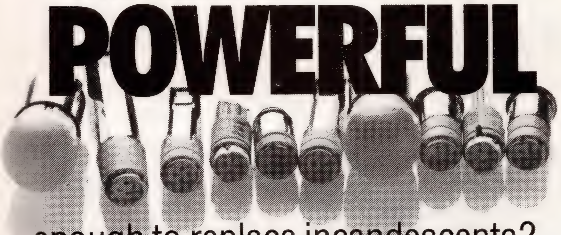

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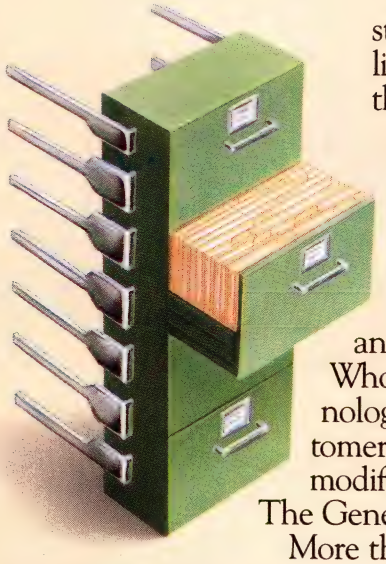
CIRCLE NO 137

Who has 10,000 silicon solutions on file?

The General.



Who will paint standard or modified linear IC's purple, form the leads to your spec, test them any way you wish, build them in a QPL plant to 883B, Rev. C and Class S, package them in SOIC, LCC, and PLCC packages? Who will use hybrid technology, screen to customer specifications, or modify an existing design? The General will. That's who.

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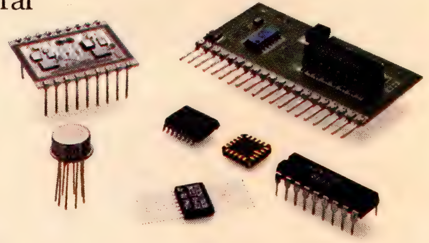
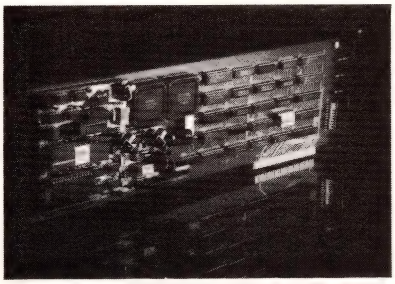


A Sampling of Silicon General Specials.

SILICON
GENERAL

CIRCLE NO 138



well as prompts for controlling the board's different modes of operation. You can configure the filters as 0- to 128-tap filters. The throughput of a filter is a function of the filter's length; the filters' processing rate is 80 nsec/tap. The board's core chip set consists of an ICL7115 A/D, which operates as fast as 25 kHz; a 29C128 FIR-filter controller; a 29C510 16-bit multiplier/accumulator; and an ICL7121 DAC. I/O takes place through edge-mounted connectors. You can bypass A/D and D/A converters on the board so that you can filter digital data from another source or store filtered data in digital form on disk. $799.

Intersil Inc, 10600 Ridgeview Ct, Cupertino, CA 95014. Phone (408) 996-5679. TWX 910-338-0171.

Circle No 371

INFRARED PRINTER

- *Handheld printer uses 4 AA alkaline batteries*
- *Uses 2.5-in. thermal paper*

The HP 82240A infrared printer provides a wireless interface by using an infrared LED that operates at a 940-nm wavelength. You can place the printer as far away as 18 in. and within a 60° arc from the sending unit. The printer has a 200-byte print buffer that holds eight 24-character lines. Its controls include a power switch, which automatically advances the paper by one line when the printer is turned on; a switch that advances the paper when the printer is not printing; and a slide control that adjusts the print darkness. The printer's 8-dot print head provides 166 dot-columns, which are sufficient for 24 columns of 5-dot-wide characters and 2 spaces between each character. The paper advances by eight dot rows after each line, making continuous graphic printing possible. The printer measures 3.6×7.3×2.5 in.; with batteries and a full roll of paper, it weighs 1 lb. The batteries provide enough power

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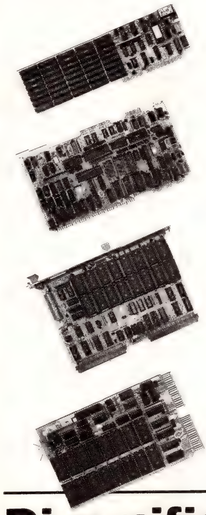

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CIRCLE NO 176

Fujitsu's line of compatible SCSI data storage products will help you drive your system to its full performance potential.

If you want cartridge tape drives, optical disk drives, 5¼-inch, 8-inch, and 10½-inch Winchester drives — or any combination thereof — on your SCSI bus, you'll never miss with Fujitsu America.

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CIRCLE NO 140

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to print approximately 6000 lines. $135.

Hewlett-Packard Co, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

Circle No 372

HARD-DISK DRIVE

- *Dual hard-disk drive provides 320M bytes of storage for PC/AT*
- *Access time is under 30 msec*

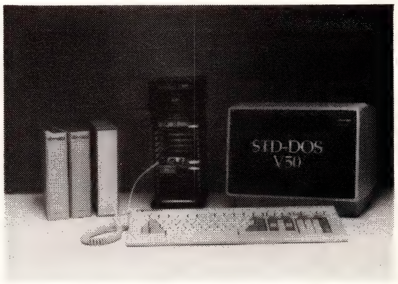
The AT160F 160M- or 320M-byte internal hard-disk drive subsystem for the IBM PC/AT and compatibles is also available in a single-drive half-capacity version. The AT160AF is supplied in a kit that includes Maxtor's XT2190 28-msec, full-height 5.25-in. drive; a ROM BIOS chip set from Award Software (Los Gatos, CA); and Speedstor hard-disk integration software from Hexis Designs (Los Gatos). The ROM BIOS is supplied in two 128k-byte chips that you install in existing sockets on the PC/AT's mother board. You can use the entire capacity of one disk as a single logical unit or partition the 320M bytes into eight logical units of varying sizes. Model AT160F-2C, the 320M-byte system, comes with 2 drives, the Speedstor software, a controller, and the BIOS. The AT160F-1 comes with one drive, the Speedstor software, and the BIOS. AT160F-1, $5795; AT160F-2C, $9995.

Storage Dimensions, 14127 Capri Dr, Los Gatos, CA 95030. Phone (408) 370-3304.

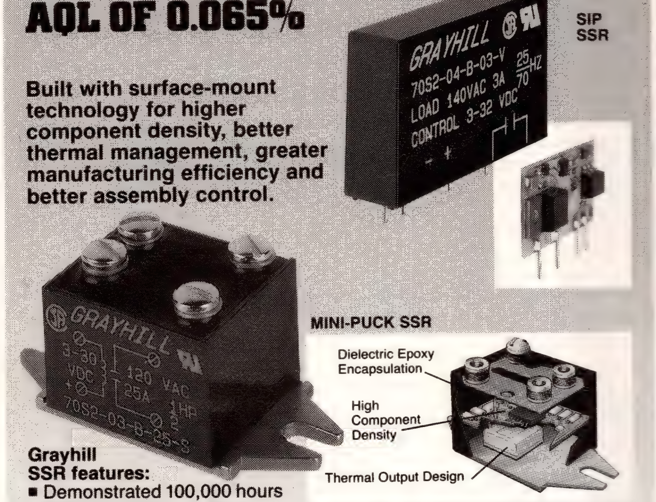
Circle No 373

SINGLE-BOARD PC

- *STD Bus-based single-board computer*
- *Combines IBM PC DOS operation with STD Bus products*



The STD DOS V50 single-board PC DOS system uses the NEC V50 μP and conforms to the STD-8088 specification. Two options, the Autoswitch EGA Video Graphics Controller (ZT 8844) and a multifunction disk controller (ZT 8850), give the system enough IBM PC compatibility to run the two most popular PC-compatibility benchmarks: Lotus 1-2-3 and Microsoft's Flight Simulator. The card includes the NEC V50 μP, 512k bytes of dynamic RAM, sockets for 256k bytes of PROM, capacity for 64k bytes of battery-backed static RAM, a real-time clock, an RS-232C and an RS-422 port, and power-fail-protection cir-



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CIRCLE NO 141

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CIRCLE NO 215

cuitry. The operating system is essentially IBM PC DOS 3.2, except that it has enhancements that make it more suitable for STD Bus-based automation applications. The PC-assisted development system, consisting of the vendor's ZT 8816 single-board computer, ZT 8863 system enclosure, cables, and documentation, costs $2700; the standalone development system, including a disk drive and user console, is $4500. The target system, including a ZT 8816 single-board computer, an STD DOS BIOS, and documentation, is $1200.

Ziatech Corp, 3433 Roberto Ct, San Luis Obispo, CA 93401. Phone (805) 541-0488.

Circle No 374

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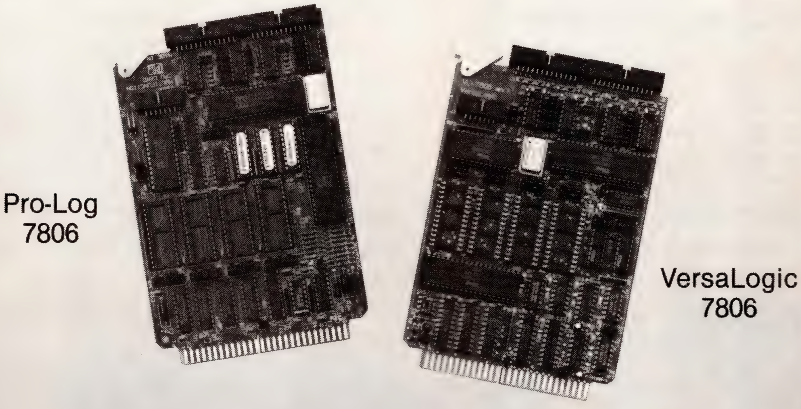

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CIRCLE NO 142

TERMINALS

- *Handheld terminal features a touch-panel interface*
- *Options include printer and bar-code reader*

The EHT Series handheld terminals feature touch-panel displays that eliminate the need for overlays because the graphics are programmable. You can program the touch panels to display icons or alphanumerics for your application by using a host computer or a smart-card interface. The EHT-11 has a PC-compatible V-20 16-bit µP, 128k bytes of RAM, an 84×154-dot display, an RS-232C port, and a 1200-bps modem. The EHT-10 uses the Z80 as its processor and comes with 64k bytes (expandable to 256k bytes) of RAM. Each terminal comes with a removable 24-column, impact dot-matrix printer, a real-time clock, a buzzer, a smart-card reader, an ac adapter and battery charger, a bar-code interface, and an RS-232C interface. Each terminal also comes equipped with an external on/off switch, a reset button, and a display-contrast knob. The power supply for each terminal consists of a rechargeable main battery and a backup battery. $600.

Epson America, OEM Products Div, 23600 Telo Ave, Torrance, CA 90505. Phone (213) 534-4500.

Circle No 375

CPU CARD

- *Includes a 68020 µP and a 68881 math coprocessor*
- *Operates on the G96 Bus*

The GESMPU-20 is a single-Eurocard, 32-bit CPU board for the G96 Bus. Based around a 12- or 16-MHz 68020 µP, the board provides you with a virtual-machine environment and an addressing range of 32M bytes. Onboard features include a 68881 math coprocessor for floating-point arithmetic, 256k or 512k bytes of static RAM, and four 32-pin sockets that you can

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CIRCLE NO 193

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Yes! Send me more information about KONTRON's IP286

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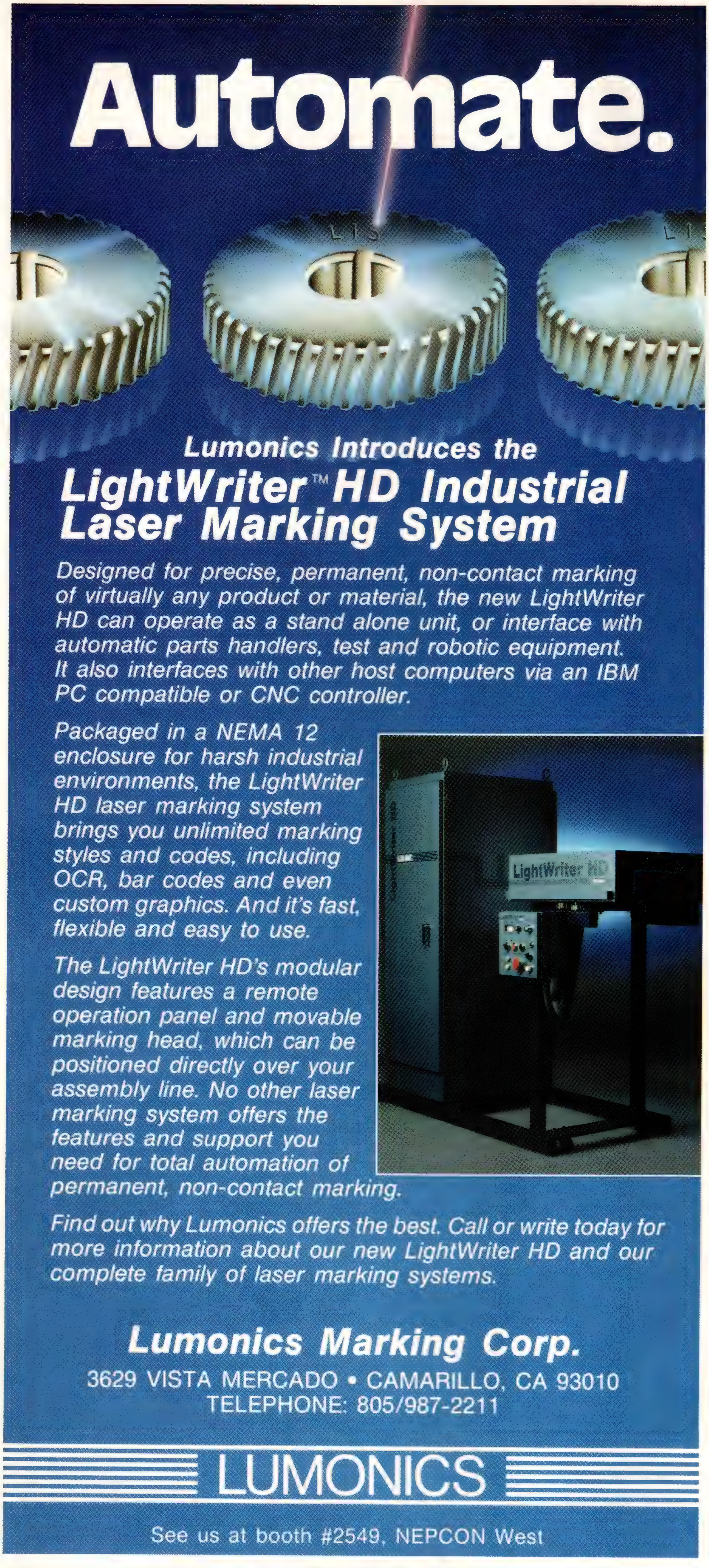

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Circle No 376

Gespac Inc, 100 W Hoover Ave, Suite 11, Mesa, AZ 85202. Phone (602) 962-5559.

Circle No 377

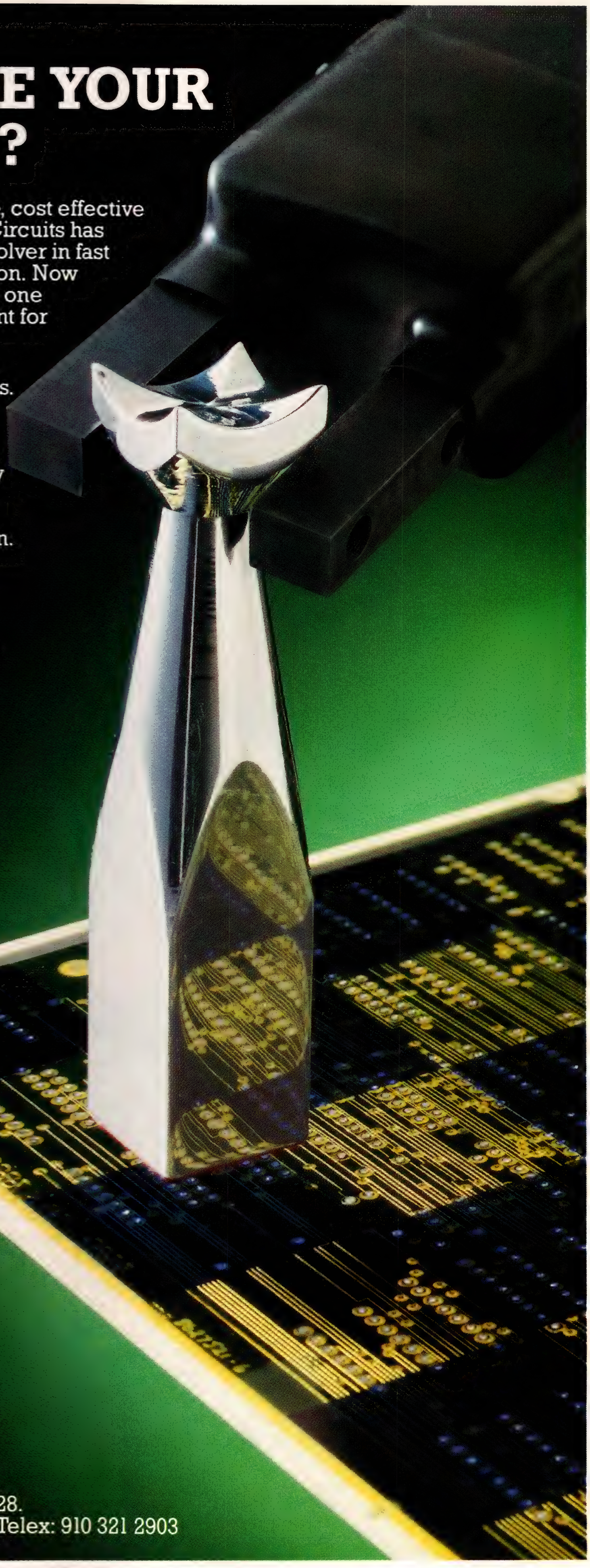
1-BOARD COMPUTER

- *Operates as a 68008-based master or slave CPU*
- *Handles 8 STE Bus lines and 14 onboard interrupt sources*

The Celeste/008, a single-Eurocard board for the STE Bus, conforms to the IEEE P1000/D3.1 bus specification. Based around a 68008 μP, the board is capable of carrying 192k bytes of memory configured in two 64k-byte EPROM sockets and two 32k-byte CMOS RAM sockets. Two 3-state RS-423/485 ports provide RTS/CTS handshaking capability and independently programmable baud rates from 50 to 38.4k baud. Alternatively, you can operate the serial ports at rates to 1M bps by using an internal or external clock source. Independent FIFO buffers on each channel reduce CPU overhead during communications. In addition, the board has two 8-bit parallel I/O ports with four handshaking/control lines, a battery-backed real-time clock/calendar, and 16- and 24-bit programmable timers. Approximately £400.

Control Universal Ltd, 137 Ditton Walk, Cambridge CB5 8QF, UK. Phone (0223) 244448. TLX 995801.

Circle No 378



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TDS CIRCUITS INC
Sunset/Vine Tower, Suite 1126,
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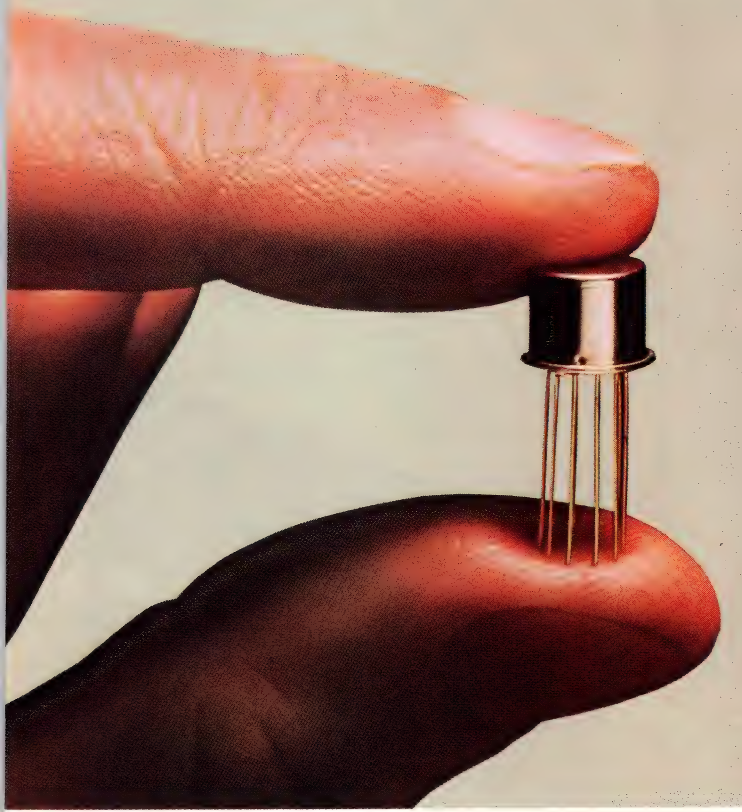
CIRCLE NO 145

Maglatch TO-5. The world's smallest relay with indestructible memory.



Our little magnetic latching TO-5 relay simply never forgets. Once it's set with a short pulse of coil voltage, Teledyne's Maglatch TO-5 will retain its state until reset. Even if system power fails or is shut off.

Because holding power is not required, the Maglatch TO-5 uses less energy than any other relay you can buy. This makes it ideal for any situation where power drain is critical. And its tiny footprint makes it ideal for high density printed circuit boards.

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The Maglatch TO-5 is available in SPDT and DPDT styles. And it comes in commercial/industrial versions as well as military versions qualified to "L," "M," and "P" levels of MIL-R-39016.

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CIRCLE NO 146

INTEGRATED CIRCUITS

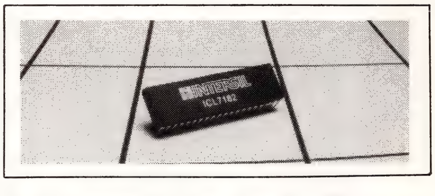
POWER OP AMP

- *Unity-gain stable*
- *260W output capability*

The OPA501/883B is a ±10A, unity-gain-stable op amp that meets the requirements of MIL-STD-883, method 5008, level B. The quiescent power level is 0.2W; peak output capability is 260W. The amplifier has output-current limiting and a fully specified safe operating area. This hybrid is packaged in an 8-pin, hermetic TO-3 can that allows direct mounting without an insulating washer or spacer. Prices for the premium V grade, specified for the military temperature range, start at $88 (100); for the U grade, specified for the industrial or military ranges, from $77.25 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TWX 910-952-1111.

Circle No 367



BAR-GRAPH ADC

- *Drives a multiplexed LCD*
- *Consumes 1.8 mW typ*

Model ICL7182 is an A/D converter that not only directly drives a multiplexed LCD but also requires only three external components to drive a 101-segment bar graph. The monolithic, silicon-gate CMOS device consumes 1.8 mW typ. Analog and reference inputs are fully differential (the chip includes a 2.56V bandgap reference). Guaranteed specs include less than 0.5% error for nonlinearity and zero offset at a 1V full-scale input. The full-scale differential input range is 200 mV to 1.1V. The part comes in a 40-pin DIP. $8.95 (100).

GE/Intersil, 10600 Ridgeview Ct, Cupertino, CA 95014. Phone (408) 996-5000. TWX 910-338-0171.

Circle No 379

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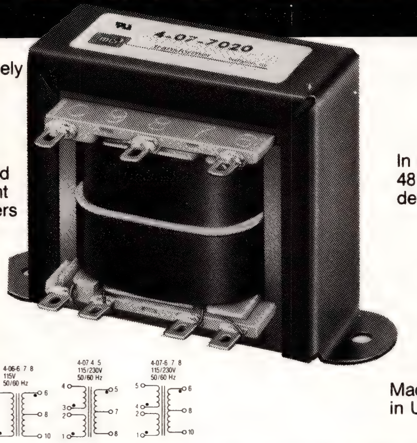

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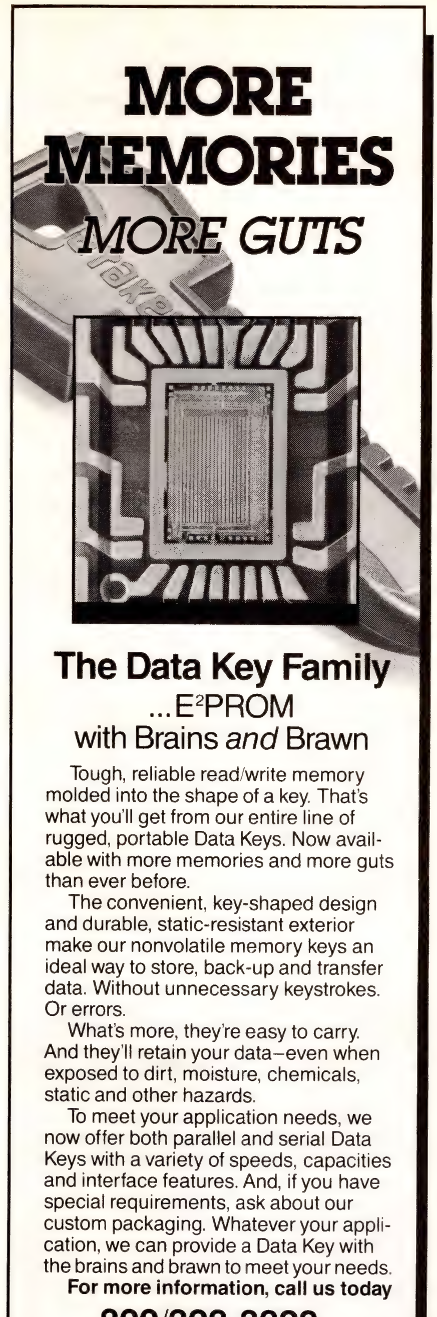

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CIRCLE NO 149

DSP CHIPS

- *Achieve throughput to 5M flops*
- *ALU does IEEE divide and square-root operations*

The ADSP-3211 floating-point multiplier achieves throughput to 20M flops and 5M flops for single- and double-precision operations, respectively; the ADSP-3221 floating-point arithmetic-logic unit (ALU) incorporates new instructions for IEEE divide and square-root operations. Each has a lower-cost, 10M-flops, single-precision version: the ADSP-3201 multiplier and ADSP-3202 ALU. All four products use 1.5-μm CMOS technology and come in 144-pin grid arrays. The ADSP-3211, for example, has two 32-bit input ports and one 32-bit output port, and it performs single-precision, floating-point multiplication with a latency of 140 nsec. Parts are specified for operation over the commercial and military temperature ranges. ADSP-3201 and ADSP-3202, from $97; ADSP-3211 and ADSP-3221, from $300 (100).

Analog Devices Inc, Literature Center, 70 Shawmut Rd, Canton, MA 02021. Phone (617) 461-3672.

Circle No 380

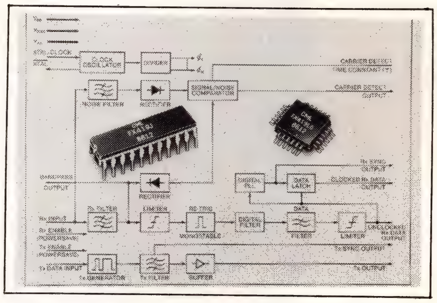
MULTIPLEXERS

- *Protected against overvoltage*
- *Guarantee on-resistance matching*

The HI-546 family of 32 analog multiplexers specs 70V p-p overvoltage protection and guarantees on-resistance matching between any two differential or single-ended inputs. Pin and function compatible with the manufacturer's HI-506A Series, this family of multiplexers features 2-μA max I/O leakage in the presence of input signals as high as 66V p-p. Model HI-546 has 16 single channels; the HI-547 is a dual, 8-channel multiplexer. Packaging options include 28-pin plastic or ceramic DIPs, 28-pin hermetic LCCs, and PLCCs. The multiplexers are available to operate in the commercial, industrial, and military temperature ranges; DESC-drawing and MIL-screened devices are available. Two smaller units, the 8-single-channel HI-548 and the dual 4-channel HI-549, come in 16-pin plastic or ceramic DIPs or in 20-pin LCCs or PLCCs. Prices range from $7.90 to $84.75 (100).

Harris Corp, Semiconductor Sector, Box 883, Melbourne, FL 32901. Phone (305) 727-9100.

Circle No 381



MODEM IC

- *Includes independent transmit and receive sections*
- *Suits battery-powered radio applications*

The FX419, a full-duplex FSK modem, meets the requirements of cellular- and trunked-radio specifications. Mark and space frequencies are 1200 and 1800 Hz, respectively; phase-continuous frequency transitions take place at zero-crossover points. The modem includes circuitry for received carrier detection and receiver clock recovery. Transmit and receive sections operate independently. One 1.008-MHz external

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CIRCLE NO 150

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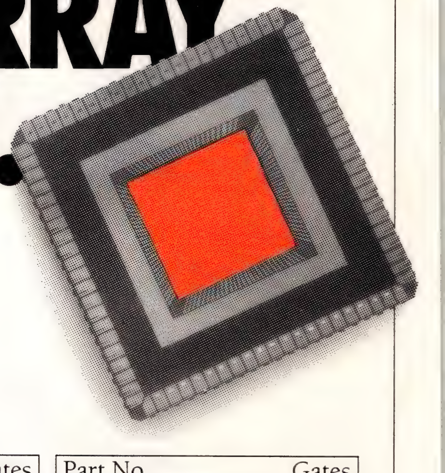

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Part No.	Gates
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LP7600L*	6100
LP7840L*	8400
LP71000L*	10000

*Available in 1987

LASERPATH
ONE DAY GATE ARRAYS™

CIRCLE NO 151

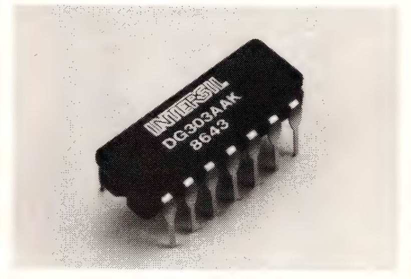
crystal controls the IC's 1200-baud rate, transmit mark/space frequencies, and Tx and Rx synchronization. An on-chip bandpass filter provides optimum carrier filtering. Implemented in CMOS technology, the modem operates from one 5V supply and consumes 4.5 mA typ with both the Tx and Rx sections enabled, thus suiting it for use in battery-powered equipment. Standby current consumption is 650 μA. Packaging options include a 22-pin ceramic DIP, a 24-pin gull-wing surface-mount package, and a 28-pin plastic leaded chip carrier. £5.29 (1000).

Consumer Microcircuits Ltd, Wheaton Rd, Industrial Estate E, Witham, Essex CM8 3TD, UK. Phone (0376) 513833. TLX 99382.

Circle No 382

Mx-Com Inc, 4800 Bethania Station Rd, Winston-Salem, NC 27106. Phone (919) 744-5050.

Circle No 383



ANALOG SWITCHES

- *Block signals as great as 30V p-p*
- *Alternate source for industry-standard switches*

This family of analog switches is fully compatible with industry-standard devices. Designated the DG300A to DG303A Series, the switches block signals as great as 30V p-p in the off state. Other features include break-before-make switching in 130 to 150 nsec, low on-resistance, and operation from a single supply (for positive switch voltages). Versions are available for operation over the commercial, industrial, and military temperature ranges. Housed in plastic or ceramic DIPs or in metal cans, $3.15 to $15.45 (100).

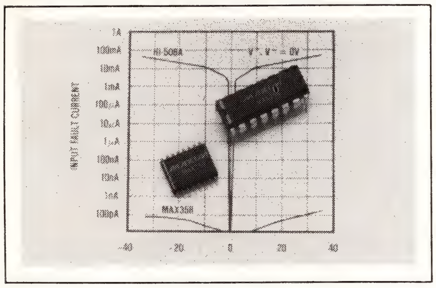
GE Intersil, 10600 Ridgeview Ct, Cupertino, CA 95014. Phone (800) 443-7364; in NY, (800) 243-7364. TWX 910-338-0171.

Circle No 384

MULTIPLEXERS

- *Reduce fault currents to nanoampere levels*
- *Withstand ±35V continuous overvoltage*

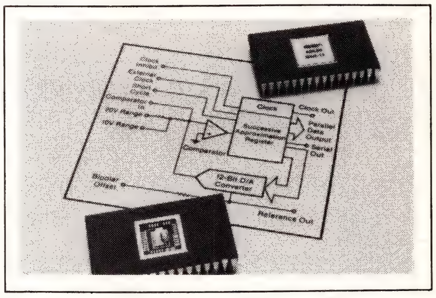
Models MAX358 (eight channels) and MAX359 (four differential channels) are analog multiplexers that offer improved fault protection compared with such devices as the HI-508A and HI-509A. Under a power-down fault condition, the units



typically allow less than 1 nA per channel of input leakage current in the presence of input voltages as high as ±35V. Furthermore, the multiplexers can withstand continuous ±35V overvoltages on all their inputs simultaneously. Other characteristics of the MAX358/359 include break-before-make switching and latch-up-proof operation in the power-down condition (even with input signals applied). The devices draw 200 µA from ±4.5 to ±18V supplies. Drain-on and drain-off leakage currents are 5 nA max; source-off leakage is 1 nA max. Both devices are available in 16-pin plastic DIPs, ceramic DIPs, and surface-mount packages. Prices for commercial- and military-temperature-range versions start at $7.35 and $17.35 (100), respectively.

Maxim Integrated Products, 510 N Pastoria Ave, Sunnyvale, CA 94086. Phone (408) 737-7600.

Circle No 385



A/D CONVERTER

- *Monolithic version of classic ADC80*
- *Specs 12-bit linearity and no missing codes over temperature*

Model ADC80MAH-12 is a monolithic design of the industry-standard ADC80 12-bit A/D converter, and it contains all the circuit blocks required by a successive-approximation ADC. The device's on-chip circuitry includes a comparator, a 6.3V laser-trimmed reference, a successive-approximation register, a clock, and associated logic. The ADC specs a 25-µsec max conversion time and guarantees ±0.012% max nonlinearity and no missing codes over −25 to +85°C. By making appropriate pin connections, you can choose bipolar input ranges of ±2.5, ±5, or ±10V, or unipolar ranges of 0 to 5 or 10V. Housed in a 32-pin hermetic DIP, the ADC80MAH-12 operates from ±12 to ±15V split supplies and a 5V logic supply. Power dissipation is 705 mW max. $35 (100).

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. TWX 910-952-1111.

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And we've left plenty of room for options. You can get the Model 621 with a quadrature square wave or TTL level pulse output. Coded digital outputs are also available in a slightly larger case.

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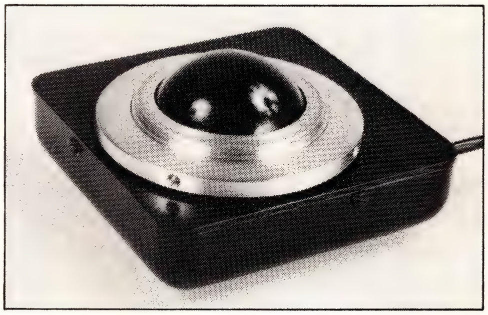

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CIRCLE NO 154

REGISTER FILE

- *Accommodates 100-MHz throughput rate*
- *Specs 10-nsec worst-case read cycle*

The Model B3210 multiport register file has two read ports, two write ports, and one bidirectional read/write port. The ECL device is organized as 64 18-bit registers; its 18-bit data word allows the IC's memory array to store byte-parity bits. Separate address lines for each port allow asynchronous, concurrent access to the memory array. You can use either transparent latches or edge-triggered registers for read addresses and data. A self-timed write pulse minimizes address and data setup and hold-time requirements. The worst-case read cycle for the IC is 10 nsec. Packaged in a 168-lead pin-grid array, the ECL-compatible B3210 dissipates 5.3W typ. A TTL-compatible version called the B2210 dissipates 3.5W typ and has a worst-case read cycle of 14 nsec. B3210, $320; B2210, $250 (100).

Bipolar Integrated Technology Inc, 1050 NW Compton Dr, Beaverton, OR 97006. Phone (503) 629-5490.

Circle No 387

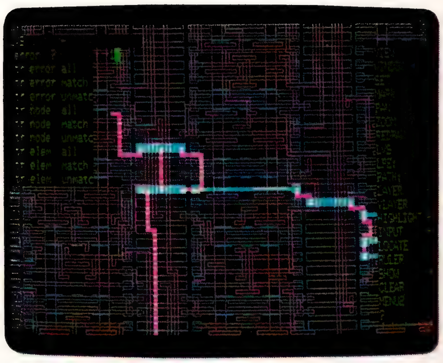
A/D CONVERTER

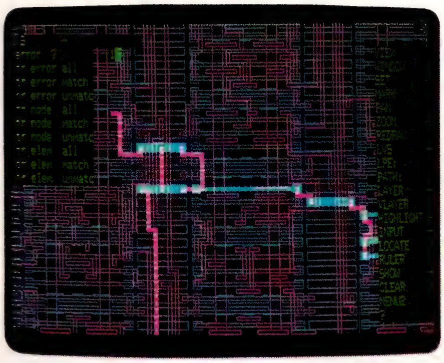
- *Samples to 8-bit resolution at 110M samples/sec*
- *Outputs data in binary or 2s-complement code*

The SP9758 is an 8-bit flash A/D converter capable of a 110-MHz conversion rate and a full Nyquist analog-input bandwidth. Accurate to better than ±0.5 LSB, it has an input capacitance of 30 pF typ and power dissipation of 1.2W typ. Only one 15.2V supply is necessary for operation. You can use the converter without the need for an external sample/hold amplifier at the ADC's input. In addition, you can configure

The $50,000 RIDGE 3200 Design Analysis.

The $400,000 VAX 8600 Design Analysis.





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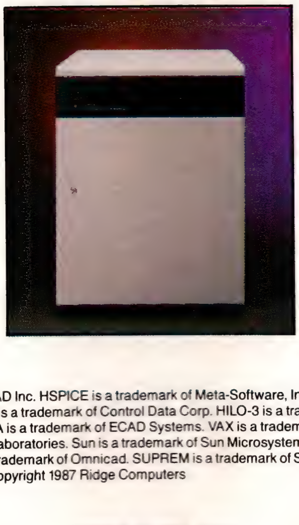
Also, with designs running 10,000–20,000 gates and larger, cost-effective real memory availability becomes as important as CPU performance. Simulations today require at least 1 Mbyte of memory for each 1,000 gates of design for efficient execution. The 128 Mbyte of real memory on the 3200 means that large designs are analyzed in memory and the overhead associated with input/output is significantly reduced. Analyses that have taken hours or days can now be done in minutes. Faster analysis provides the opportunity for more analyses and means fewer errors, lower manufacturing costs, faster product introductions, higher quality products. Success!

So remember, in addition to all of the performance and memory you would expect in a $400,000 computer, the RIDGE 3200 gives you something else. About $350,000 in change.



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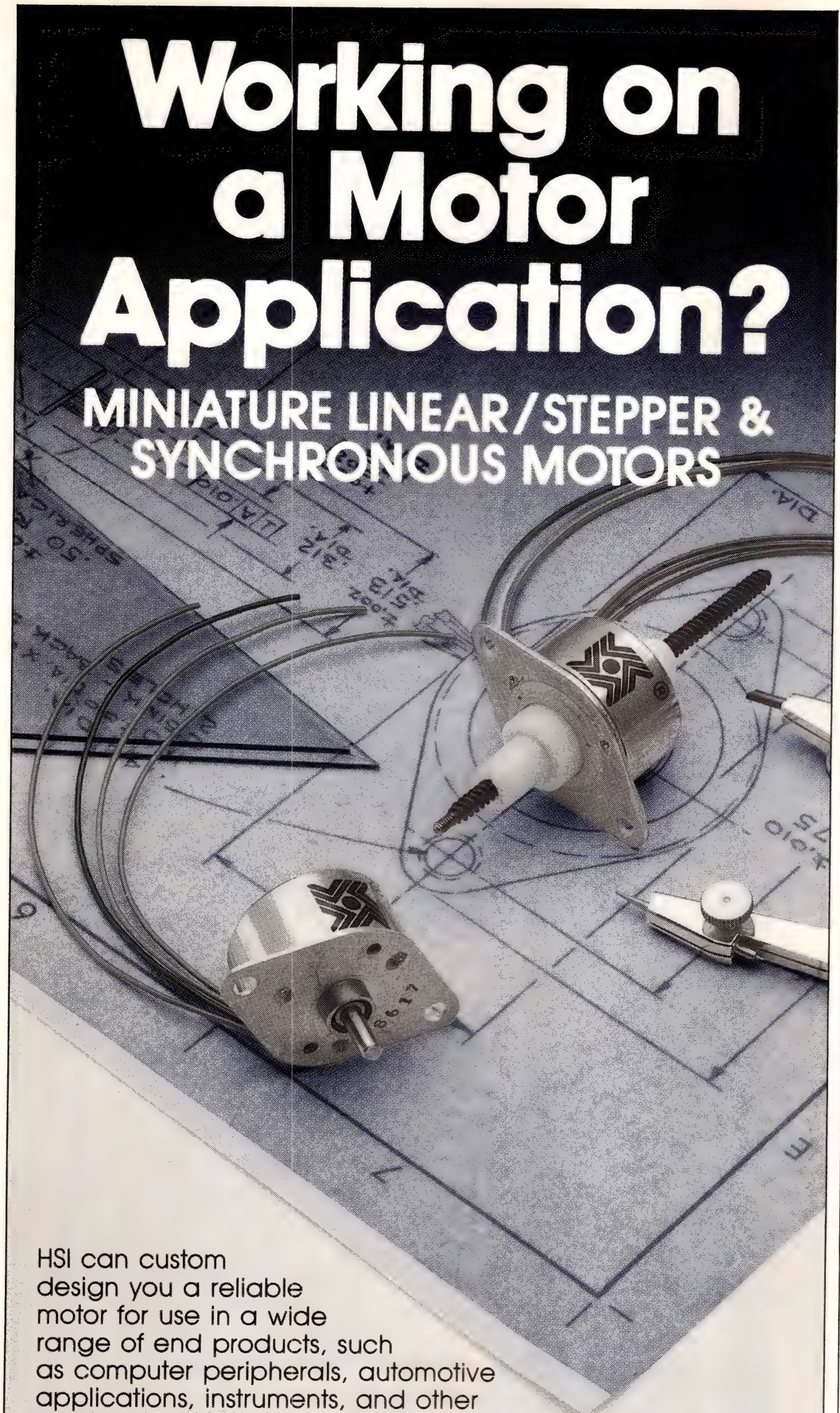
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it to produce either true- or inverse-binary or 2s-complement output coding. The converter's ECL-compatible outputs are internally latched to maximize the data-valid period. The operating range is −40 to +85°C. The part comes in a 42-pin ceramic DIP that's pin and function compatible with industry-standard 8-bit A/D converters. £84 (100).

Plessey Semiconductors Ltd, Cheney Manor, Swindon, Wiltshire SN2 2QW, UK. Phone (0793) 36251. TLX 449637.

Circle No 388

Plessey Semiconductors, 3 Whatney, Irvine, CA 92718. Phone (714) 951-5212.

Circle No 389

MOTOR DRIVER

- *Drives 3-phase brushless dc motors*
- *Accepts Hall-effect differential outputs*

This high-current linear IC drives 3-phase brushless dc motors. Model L6230 accepts differential outputs from Hall-effect sensors; the device includes the commutation logic required for 3-phase bidirectional drive. A speed-control input regulates the base current of its three output transistors in order to limit the motor's current and speed. Furthermore, the IC controls the rise and fall times of the output voltage to limit EMI noise generation. Other features include compatibility with any F/V converter or phase-locked-loop control system. You can control the direction of rotation by using a single TTL-compatible input pin. Operating from a single supply (to 18V), the device provides output currents as high as 3A. Housed in a 15-lead package dubbed Multiwatt, the IC costs $4.70 (1000).

SGS Semiconductor Corp, 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. TLX 249976.

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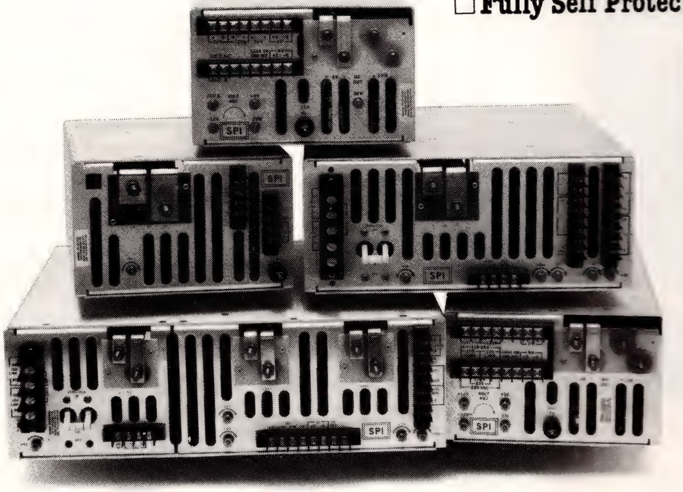

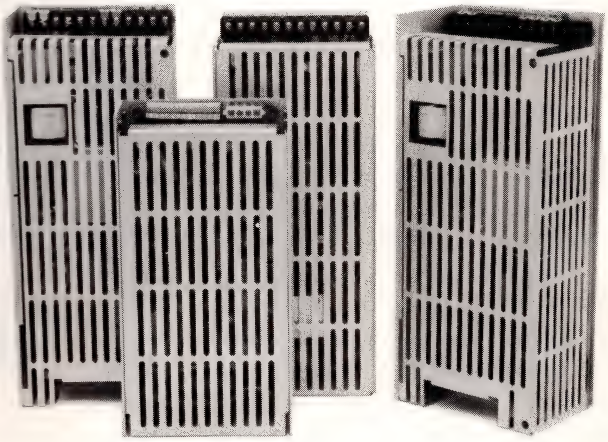

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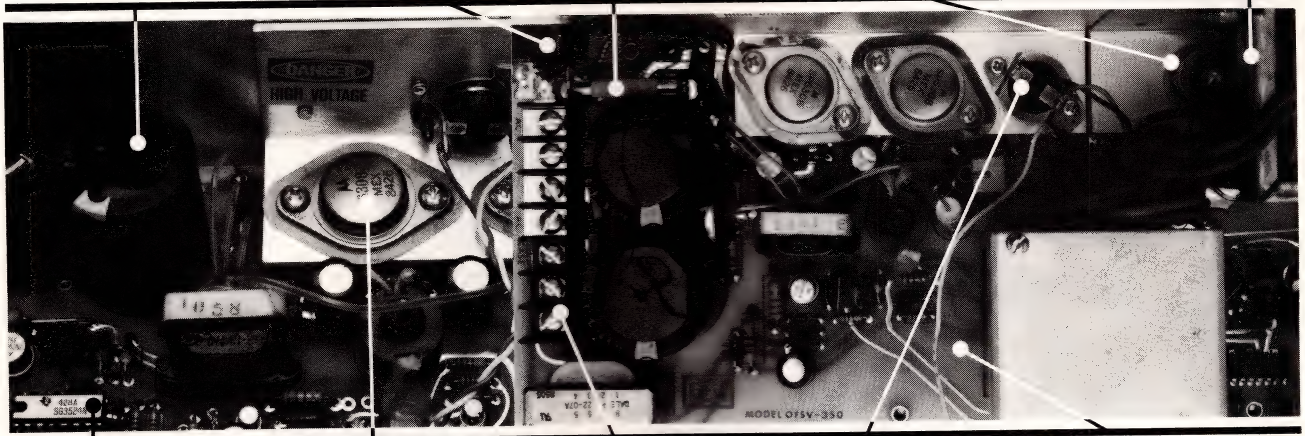

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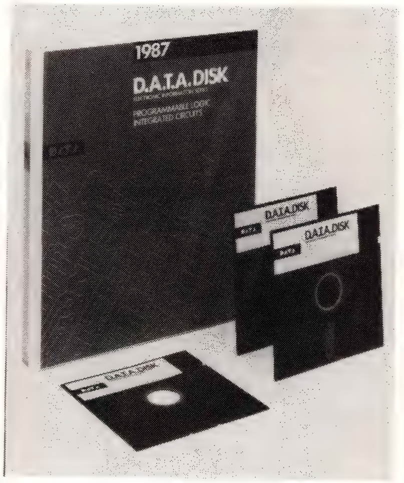
- *Runs on IBM PCs and compatibles*
- *Lists more than 3000 programmable-logic ICs*

The first product in the DataDisk Series contains a database of more than 3000 programmable-logic ICs available from more than 25 manufacturers. The database includes the most recent devices, such as logic arrays, array logic, logic sequencers, generic array logic, and radiation-hardened array logic. You can access the database by part number, by generic number, or by specifying as many as five of the desired electrical characteristics. To use the database, you'll need an IBM PC, PC/XT, or PC/AT equipped with a hard-disk drive and at least 512k bytes of RAM. One-year subscription, $80.



DATA Inc, Box 26875, San Diego, CA 92126. Phone (800) 854-7030; in CA, (800) 421-0159.

Circle No 391

CAD DATABASE

- *Runs on the IBM PC/AT and compatibles*
- *Provides interfaces to most simulation and test systems*

The Calos 6000 is a schematic-capture editor and database that consists of five major components. The first, Template, generates symbol outlines, pin names, and other attributes of a selected component. You select components from the library, which includes parts from most currently available IC families. You can create data for new components and add them to the library. Another part of the program, Package, combines a set of templates to form a component. During package development, the program checks for errors such as duplicated pin num-

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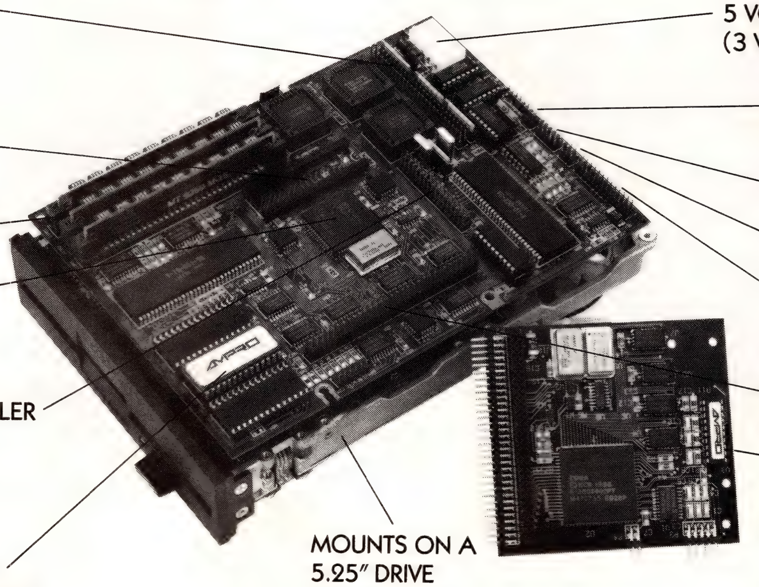
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CIRCLE NO 158

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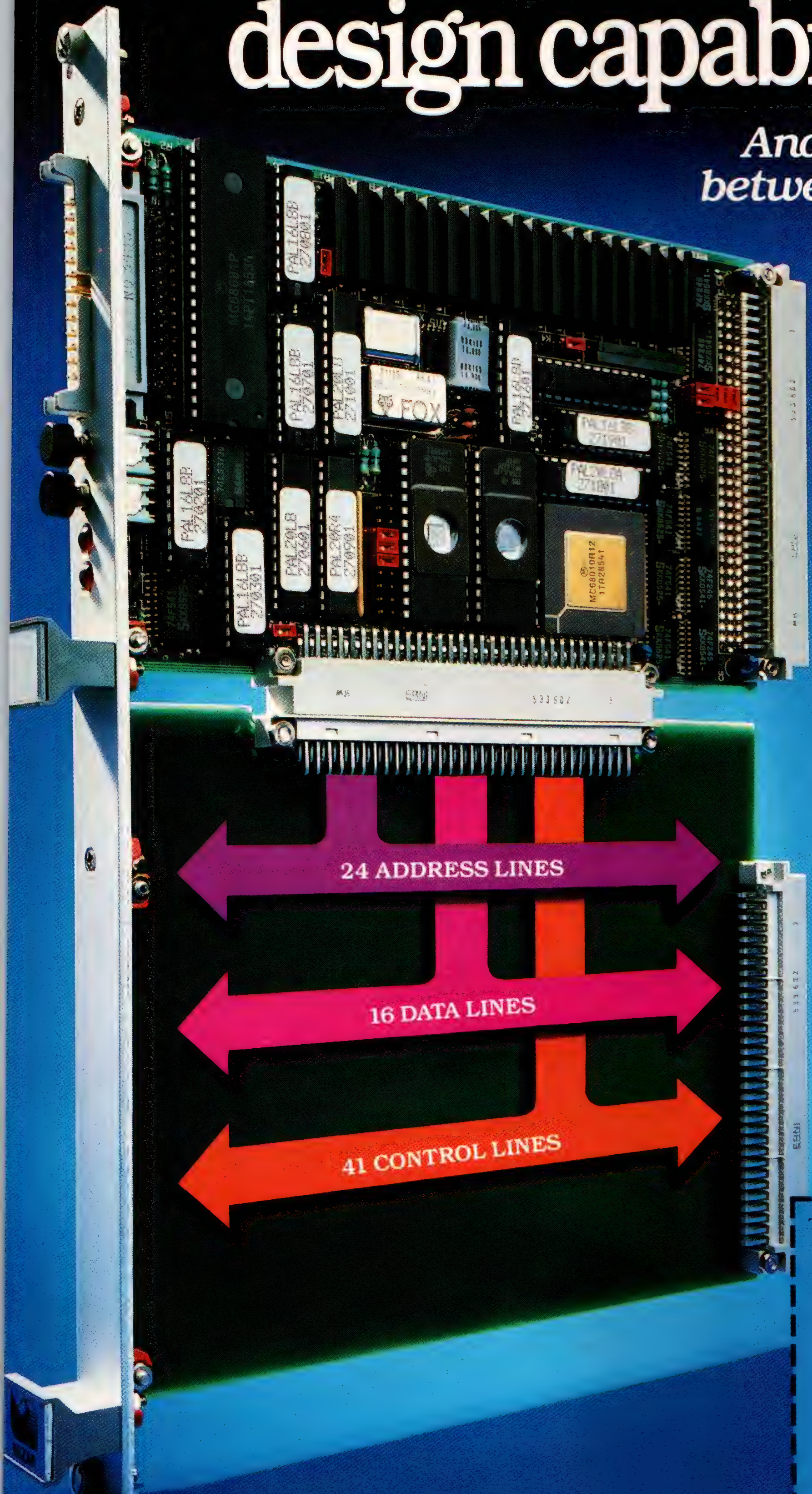

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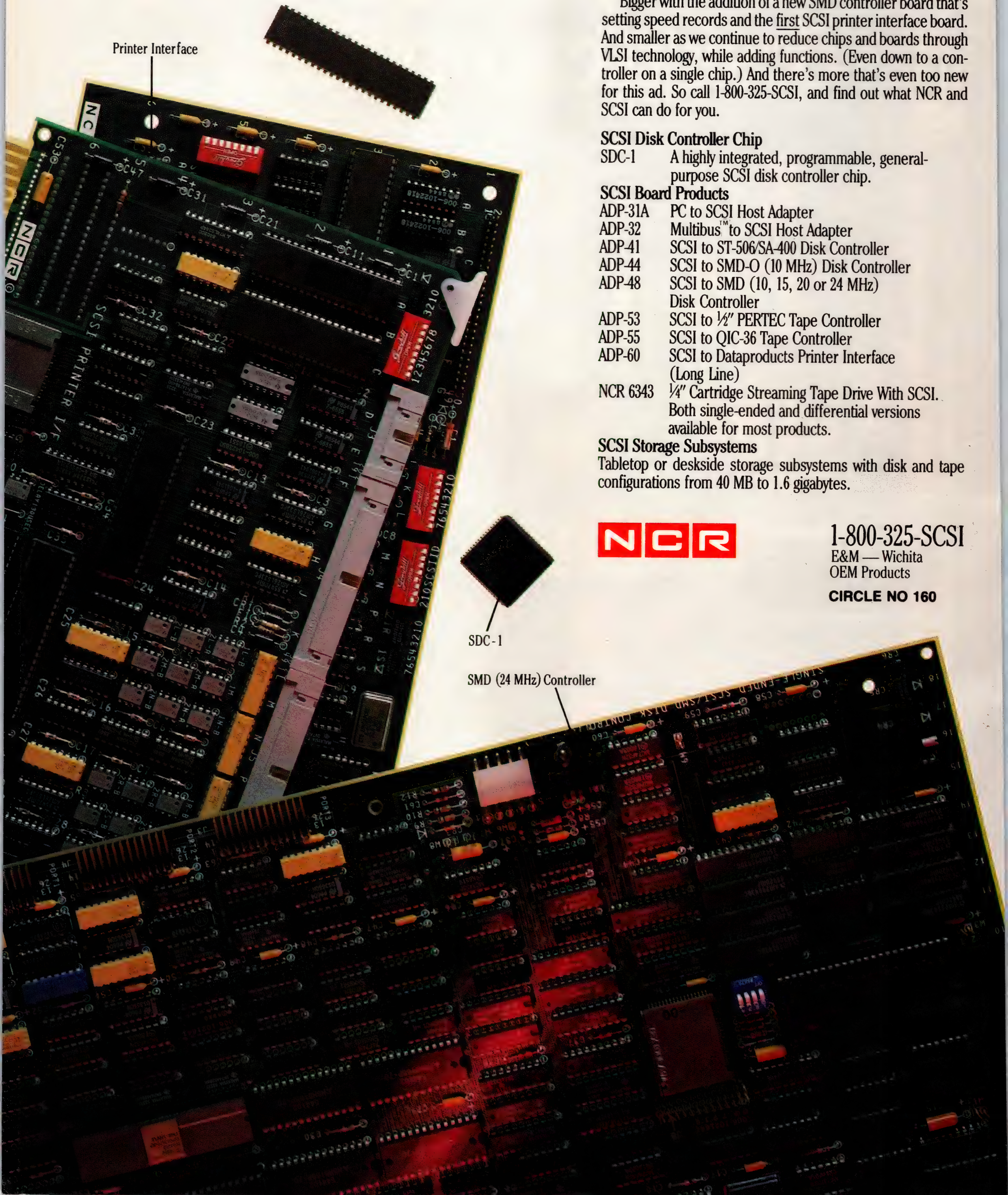

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CIRCLE NO 160

bers, omission of standard power and ground pins, and pin-to-pin mismatch. Another component, Alternate, lets you select equivalent symbol representations of a part and toggle between them without affecting the gating; you can use this feature to show negative logic symbols and mirrored representations, and you can employ it in other design procedures. Alias lets you use the same library for parts with identical graphics representations but different parametric data; you access the relational database by the part number. Family lets you choose resistors, capacitors, and other components without knowing the part number; you select the family and scroll through the available values to find the correct part. The package has bidirectional interfaces to most major pc-board layout systems, so you can optimize the layout and automatically transfer any corrections back to the schematic. Software only, $7995; complete TeleVideo TeleCAT-286 system with Calos 6000 software, $13,000.

Calos Inc, 3419 Edison Way, Fremont, CA 94538. Phone (415) 657-4430.

Circle No 392

MODULA-2 COMPILER

- *Generates native 8086/88 code*
- *Includes a Make utility*

The vendor's Modula-2 compiler runs on any 8086/88-based machine under IBM PC-DOS or generic MS-DOS. It provides all features of the Modula-2 language as defined by Niklaus Wirth in *Programming in Modula-2*. The compiler generates an intermediate file during the first pass, during which it performs all lexical and syntactical analysis. During the second pass, the compiler processes internal symbols from the executable code. The algorithms used in these two passes allow you to write source code in which you can use symbols before you have defined them. The code generator reads one procedure at a time from the intermediate file, performs the analysis in memory, and produces executable code for that procedure before going on to the next one. According to the vendor, these algorithms result in more rapid compilation, with fewer disk accesses, than can be obtained from other 4-pass compilers. The compiler package includes a Unix-like Make utility, as well as complete source code and object code for the run-time library. The compiler package is not copy protected, and the vendor charges no royalty fees on code produced by the compiler for inclusion in commercially developed programs. $89.95.

Farbware, 1329 Gregory, Wilmette, IL 60091. Phone (312) 251-5310.

Circle No 393

CAM/CAT SOFTWARE

- *Provides data to drive insertion and N/C equipment*
- *Optimizes design of test fixtures*

The CAM/CAT Toolbox accesses the vendor's design database to obtain accurate and consistent data for the manufacturing and testing phases of pc-board production. The package consists of three modules. The CAM Data Generator extracts from the database all the information needed to drive autoinsertion and wire-wrapping equipment. You can list and sort the data according to machine-specific requirements. The FXT Data Generator cross-references the net database against the final layout and optimizes the locations of the probes in a test fixture so that there is a probe for the source of every signal, including external signals applied to an edge connector. The program lets you create a series of color-keyed plots to assist manufacturing personnel in locating probe positions. The CAT Data Generator extracts net lists from the database in the format required by your automatic test

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equipment. CAM Data Generator, $3750; FIXT Data Generator, $3000; CAT Data Generator, $7500.

Telesis Systems Corp, 2 Omni Way, Chelmsford, MA 01824. Phone (617) 256-2300. TLX 948143.

Circle No 394

LISP FOR MAC

- *Compiles native 68000 code directly from Lisp source code*
- *Manages memory and optimizes space*

Expercommon Lisp, which runs on the Macintosh, generates native 68000 code directly from Lisp source code. It features more than 1100 Lisp primitives; a memory-management technique that keeps in memory only the routines currently in use; and an on-line, automatic symbolic debugger that identifies errors and allows you to trace the program path back to the source of the error. You can resume program execution as soon as you have corrected the error. The package provides a class system with a full set of tools for object-oriented programming. It also allows direct access to the Macintosh Toolbox, which contains development tools. Optionally, the vendor offers a dead-code analyzer that removes from the Lisp kernel all tools that are not specifically needed for a particular application program. Use of the analyzer results in smaller, faster application programs, the manufacturer claims. Expercommon Lisp, $995; dead-code analyzer, $1500.

Expertelligence Inc, 559 San Ysidro Rd, Santa Barbara, CA 93108. Phone (805) 969-7874.

Circle No 395

CROSS-COMPILER

- *Lets you develop Lisp programs on a Lisp machine*
- *Lets you run the programs on a 68000-based target machine*

The Common Lisp Cross Compiler, written by Lucid Inc (Menlo Park, CA), runs on 3600 Series machines and lets you use all of the vendor's Genera tools and debugging facilities. It lets you develop application programs that will run on the ven-

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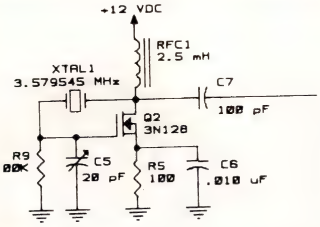

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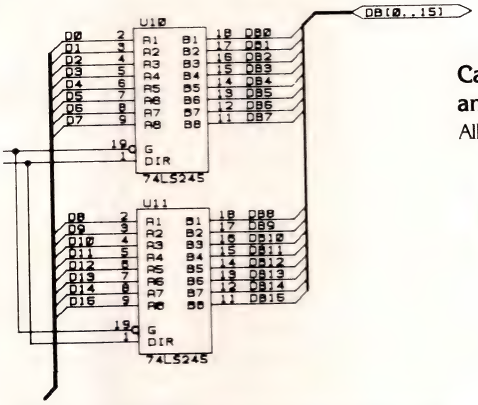

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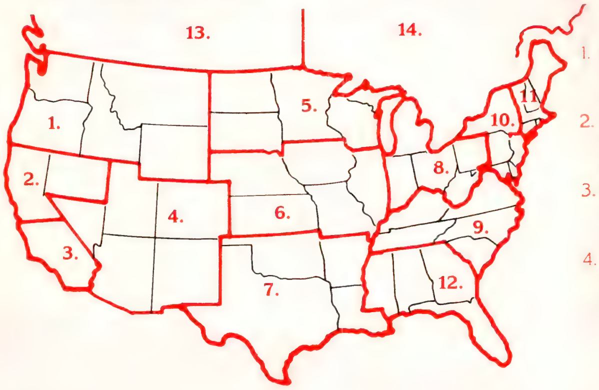

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Elcor Associates, Inc.
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714-897-0319

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612-788-9234

6. NE, KS, IA, MO, IL
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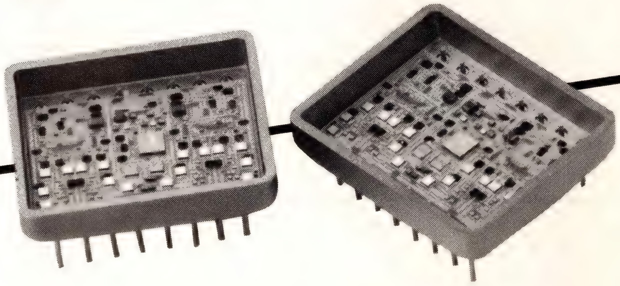
The companion LR6006 receiver provides the necessary matching impedance to the signal on the transmission line. It features a differential input designed to reject large common mode signals while responding to small differential signals. The output is TTL compatible. It operates from a ±5 V logic supply and has an input voltage range of ±5 V. Power dissipation is 600 mW. Termination resistors are included in the circuit. It also has a fail-safe operating mode which provides a steady binary condition to protect against certain fault conditions.

Both the LD6005 and LR6006 are designed to the requirements of MIL-STD-188-114A Type II & III. These devices are available with MIL-STD-883C Method 5008 Class B screening.



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Delivery for the LD6005 is stock to 8 weeks, priced $179 military & $144 commercial (100 piece lots). Delivery for the LR6006 is stock to 12 weeks, price is $78 & $63 commercial (100 piece lots).

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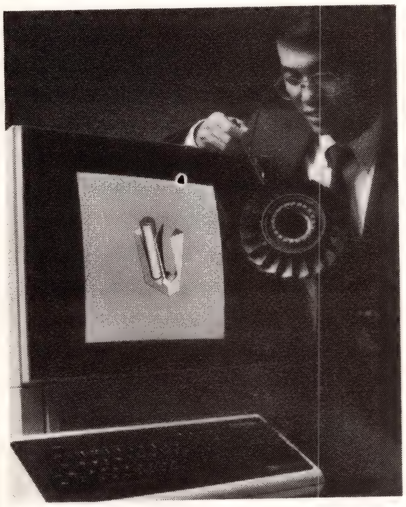
CIRCLE NO 120

dor's other machines, or on 68000-based machines, under Lucid Common Lisp. You can integrate the cross-compiler into the Genera software-development system for 3600-series machines. If the target machine is one of the vendor's application-delivery machines, you can incorporate all of the vendor's enhancements to Common Lisp in your application; however, if the target is a 68000-based Sun or Apollo workstation, you will have to restrict your application program to the features provided by Lucid Common Lisp. You'll need Genera version 6.1 or higher for the 3600-series system and Lucid Common Lisp for the target machine. Cross-compiler, $11,900.

Symbolics Inc, 4 New England Tech Center, 555 Virginia Rd, Concord, MA 01742. Phone (617) 259-3600.

Circle No 396



N/C VERIFICATION

- *Converts N/C tape to image on workstation screen*
- *Animation shows the exact operation of N/C milling machine*

The NC-Verification software package runs on Calma CAD/CAM workstations and is an optional enhancement to the vendor's Prism/DDM CAE system. For each part that is to be produced, the software con-

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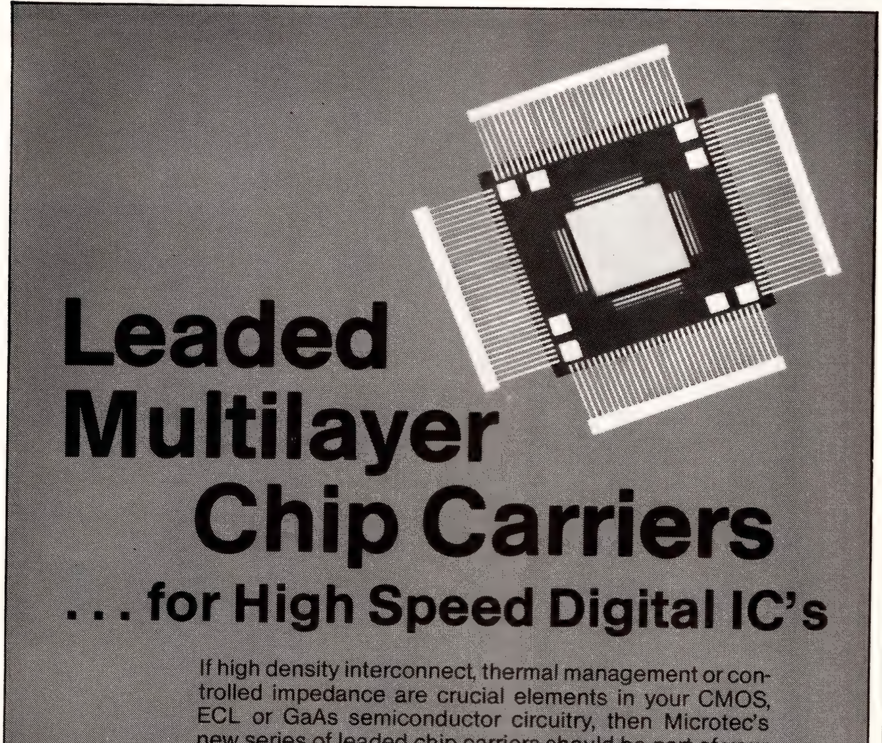
CIRCLE NO 166

verts milling-machine instructions on the numeric-control tape into a shaded-color simulation on the screen of a workstation. The image simulates the operation of the cutter on the desired part. If erroneous instructions cause the tool to cut the wrong shape or slice into the holding clamps, you can see the mistake on the screen, modify the instructions, and then replay the tape to make sure the error has been properly corrected. You can interrupt the program at any stage to compare the tool paths machined with the original design stored in the computer's memory, or to store work in progress for later completion. You can scan, rewind, or search for information about a specific part. The simulation software also estimates cutting forces and tool deflection, so you can calculate the optimal feed rate for production. According to the vendor, a complex verification, which would have required weeks to complete by conventional methods, was completed by the software package in seven hours; the package also eliminated the need to machine a sample part. $5000 to $20,000, depending on options.

Calma Co, 501 Sycamore Dr, Milpitas, CA 95035. Phone (408) 434-4000.

Circle No 397



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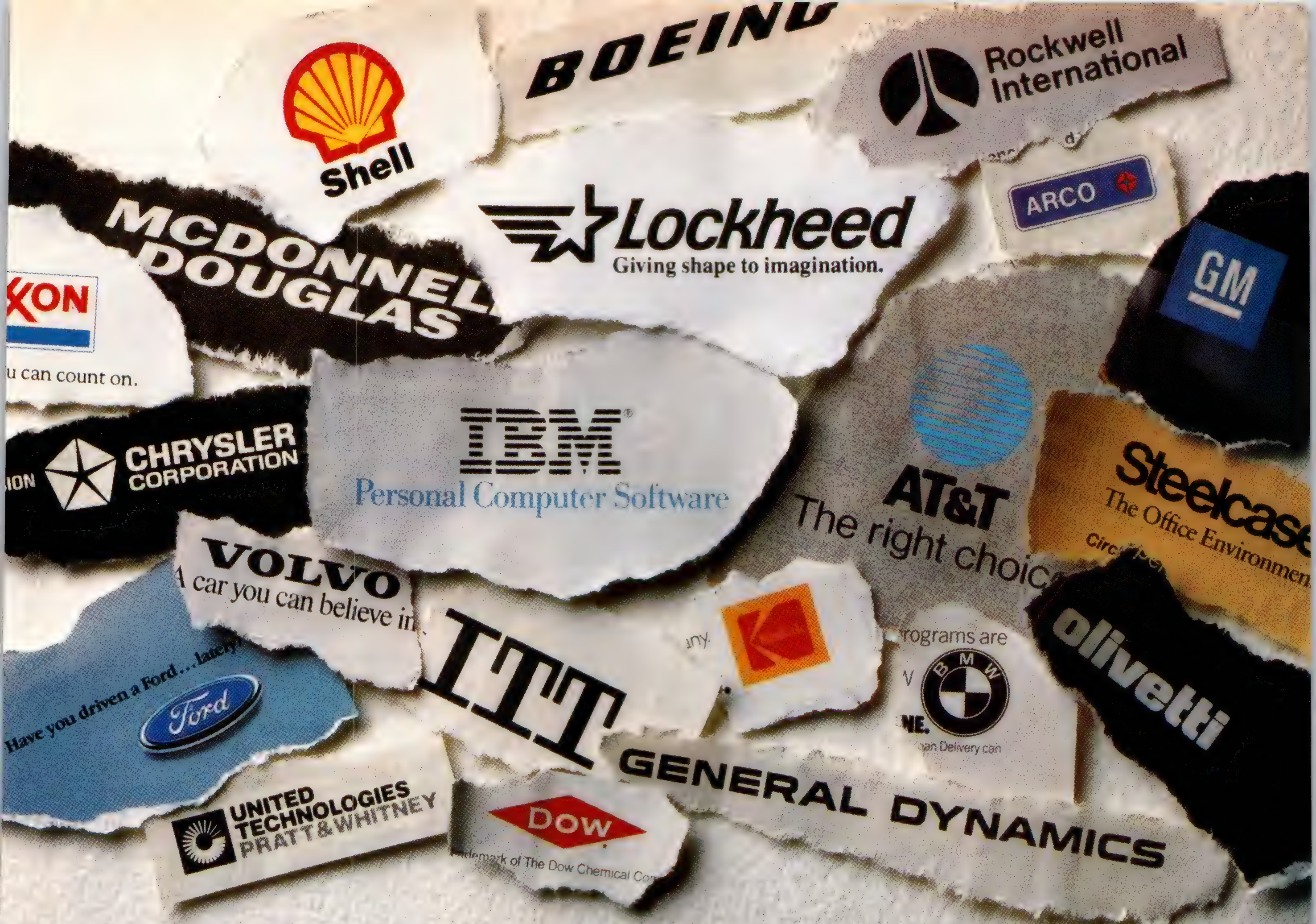
CIRCLE NO 167

APPLE SPECTROSCOPY

- *Lets you acquire and analyze spectrometer data*
- *Graphics routines can plot samples in windows*

Spectrochart is a spectrum-analysis package for an Apple IIe equipped with 128k bytes of RAM and the vendor's Adalab data-acquisition board, which interfaces to most spectrometers. A special version of the program lets you control a Milton Roy (Rochester, NY) Spectronic 1001 spectrometer via the latter's RS-232C serial interface. The program lets you set up a file to control the sequence of operations. You can specify as many as 100 standards and unknown samples for analysis in any sequence. For each sample, the program records a single absorbance, transmittance, or concentration value; for kinetic studies, the program can record multiple, timed values. The program can also record a spectrum as the spectrometer scans. It can display the results both numerically and graphically as a scrolling strip chart, and it can send this output to either the screen or the printer. The graphics routines let you display multiple samples, kinetic curves, or spectra in windows that may be as large as 560×192 pixels. Post-run analyses include conversions from transmit-



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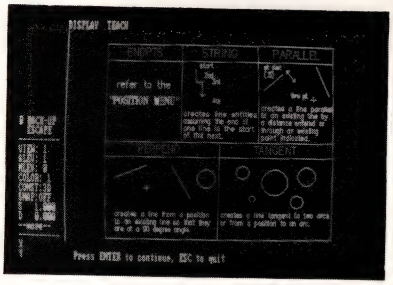
CIRCLE NO 169

tance to absorbance and measurements of peaks. A learning mode lets you record a procedure of as many as 50 steps, so that you can repeat this procedure automatically for future runs. The analysis routines can construct a standard curve by least-squares curve-fitting on as many as 25 standards and duplicates. The routines can then use the standard curve to compute an amount or concentration for as many as 97 unknown samples, corrected for dilution. Standard version, $495; Spectronic 1001 version, $695.

Interactive Microware Inc, Box 139, State College, PA 16804. Phone (814) 238-8294.

Circle No 398



Press ENTER to continue, ESC to quit

CAE TRAINING

- *Guides a user through features of a system*
- *Provides step-by-step examples of design*

CAD Expert is a computer-aided instruction (CAI) program that runs on the IBM PC and compatibles. It guides a new user through the standard features and latest capabilities of the vendor's CADkey CAE system, which also runs on the IBM PC. The package has three components: an on-line tutorial program, a demonstration disk, and a user-training manual. The tutorial disk files give step-by-step instructions on how to use CADkey functions; these functions fall into 12 major groups, including geometric modeling, detail drafting, display manipulation, entity management

You're not gambling with quality when you buy low-cost T70 relays from P&B.

Quality at just 77 cents

UL recognized and CSA certified, Potter & Brumfield's T70 relay switches from 1 milliamp through 10 amps, resistive, on printed circuit boards. All with the same reliability and performance that have made P&B relays the industry standard. And the T70 costs as little as 77 cents in 25,000 piece quantities.

Broad range of ratings

Gold-plated fine silver or silver-cadmium oxide contacts are available in a single pole, double throw configuration. Contacts of either material are UL recognized to switch motor loads up through 1/4 horsepower at 120 volts AC. Silver-cadmium oxide contacts are also rated for 5 amp tungsten lamp loads at 120 volts AC, while silver is rated 3 amps tungsten.

Reliability? Of course!

The T70 relay features simplified construction that enhances reliability while holding cost down. A sealed version is designed for immersion cleaning, and a plastic dust cover model is also available.

Off-the-shelf service

With 20 different T70 models available from stock at P&B, the unit you need is probably available off-the-shelf. Your P&B distributor or sales representative will gladly help you select the model that's just right for your application. Call toll-free 1-800-255-2550 for the name of an authorized Potter & Brumfield distributor or sales representative serving your area. Or call your P&B regional office.

Write for free sample

Write us on your company letterhead, briefly describing your potential application for T70 relays, and we'll rush you a free sample and complete specifications. Potter & Brumfield, A Siemens Company, 200 South Richland Creek Dr., Princeton, Indiana 47671-0001.

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(0454) 616263.

Potter & Brumfield A Siemens Company

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Potter & Brumfield Inc., 200 S. Richland Creek Dr.,
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☐ Please send more information about P&B T70 relays.

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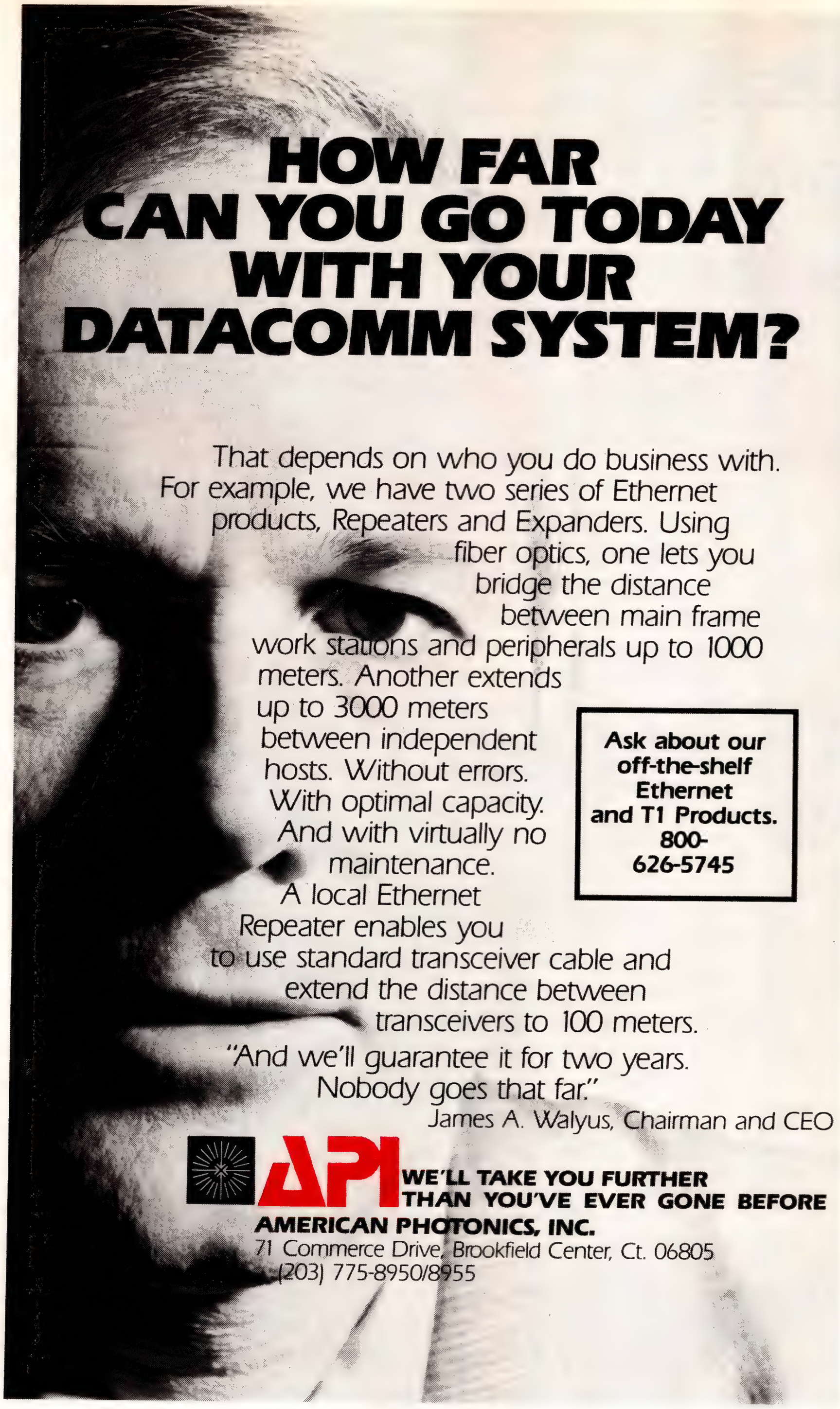

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and verification, geometric analysis, and printing and plotting. The demonstration disk contains an interactive program for practicing what you have learned from the tutorial files. The user-training manual includes samples of CADkey 3-D designs and typical steps used in the design of various components. $395.

Micro Control Systems, 27 Hartford Tpk, Vernon, CT 06066. Phone (203) 647-0220. TWX 510-600-7223.

Circle No 399

ASIC TOOLS

- *Include symbol libraries and design tools*
- *Provide pre- and post-layout back-annotation*

Symbol libraries and design tools for LSI Logic's ASICs are now available on the Cadnetix family of workstations. The libraries include the vendor's LL5000, LL7000, and LL9000 Series HCMOS array libraries; the tools include pre- and post-layout back-annotation of gate and interconnect delays, as well as manufacturing interfaces to an LSI Logic Design Center. During the schematic-capture phase of design, you work with macrocell libraries certified by LSI Logic. Because the vendor's workstation includes models for individual macrocells, you can perform logic simulation either on the workstation or on IBM PCs connected to the workstation via a high-speed local network. You can simulate the circuit first with unit delays and then with estimated delays incorporated, after which you send the design to an LSI Logic Design Center for physical layout. The symbol library and net-list components of the package reside on a 68020-based server; a PC can access them via the network. $25,000.

Cadnetix Corp, 5757 Central Ave, Boulder, CO 80301. Phone (303) 444-8075.

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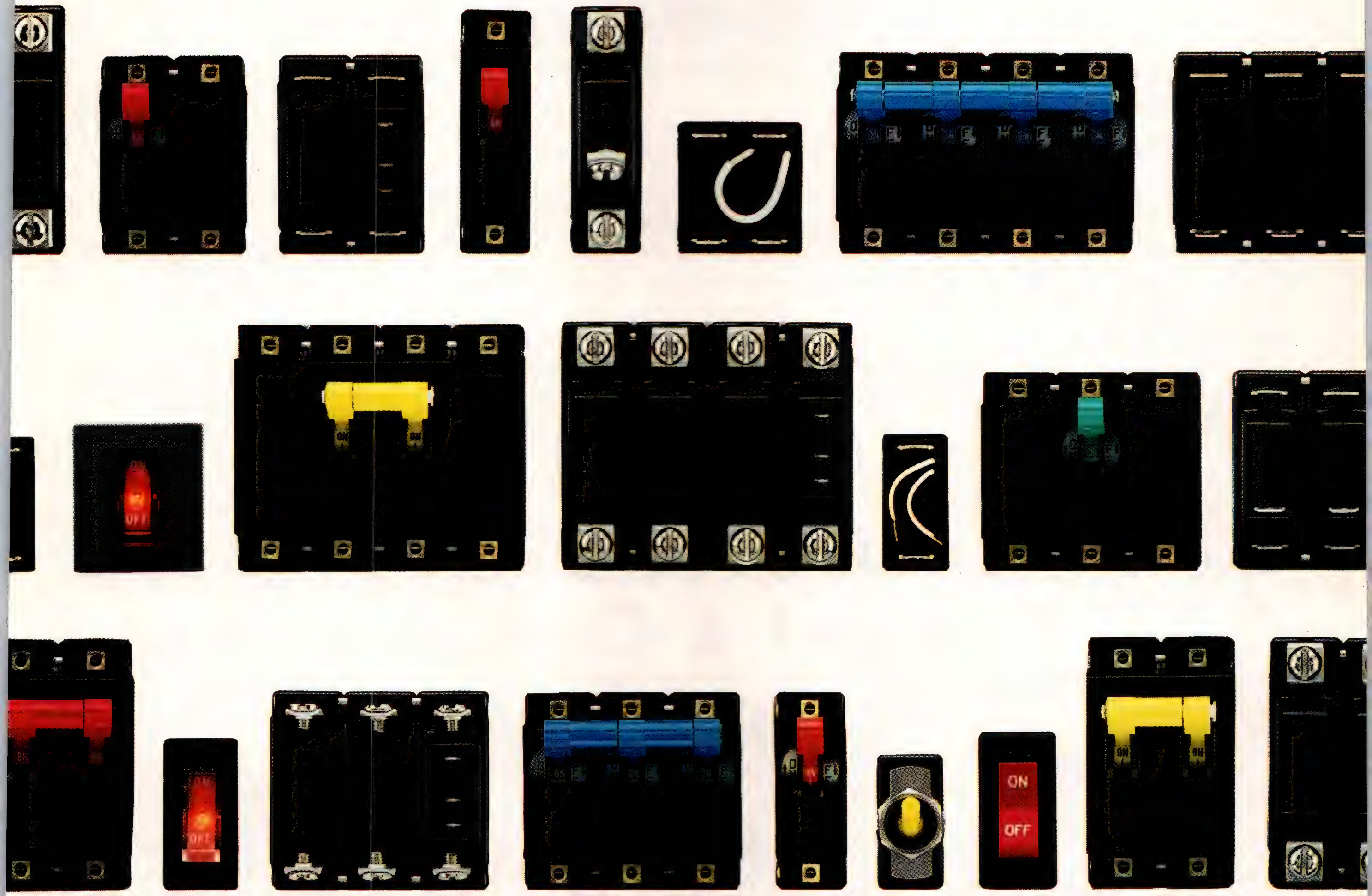

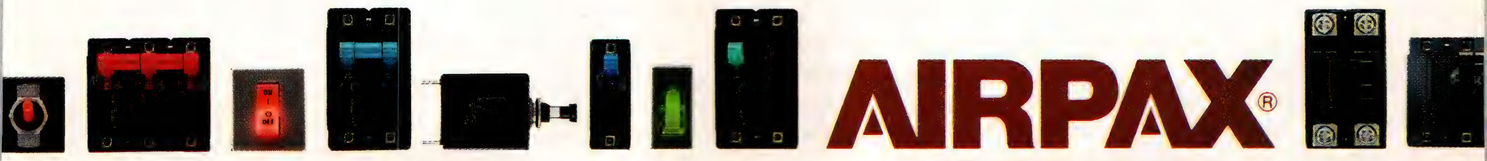

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CIRCLE NO 172

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

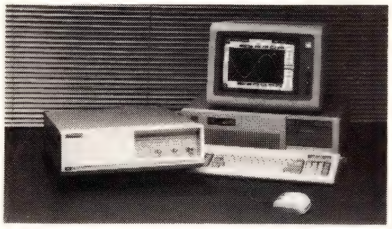
DIGITAL ATE

- *Uses IBM PC as test controller*
- *Tests 24-pin TTL devices*

The PTS-100 tests digital devices having as many as 24 pins. The tester comes with a library of tests, written in a specialized version of Basic, for more than 500 TTL devices. The tester has 24 bidirectional test pins, a programmable power supply for the DUT (device under test), and a dc PMU (precision measuring unit). Its options include a device-handler interface and test routines. The tester uses an IBM PC or compatible computer as a controller. $9950.

Pragmatic Test Systems Inc, 1405 Milpitas Blvd, Milpitas, CA 95035. Phone (408) 943-3200.

Circle No 401



WAVEFORM DIGITIZER

- *Digitizes at 1G samples/sec*
- *Comes with FFT software*

The Model 3000 waveform digitizer sports a 1-nsec, real-time sample interval (1G samples/sec). When measuring repetitive signals, the instrument can achieve 10-bit resolution. The instrument requires an IBM PC for control. The firm supplies IBM PC software that can control as many as eight digitizers at once. The software displays captured data in the time and frequency domains. The PC can display a new FFT at least once per second when the digitizer is in the continuous-acquisition mode. Model 3000, $28,500. Delivery, 60 days ARO.

Sequence Inc, 1650 Zanker Rd, San Jose, CA 95112. Phone (408) 436-6065.

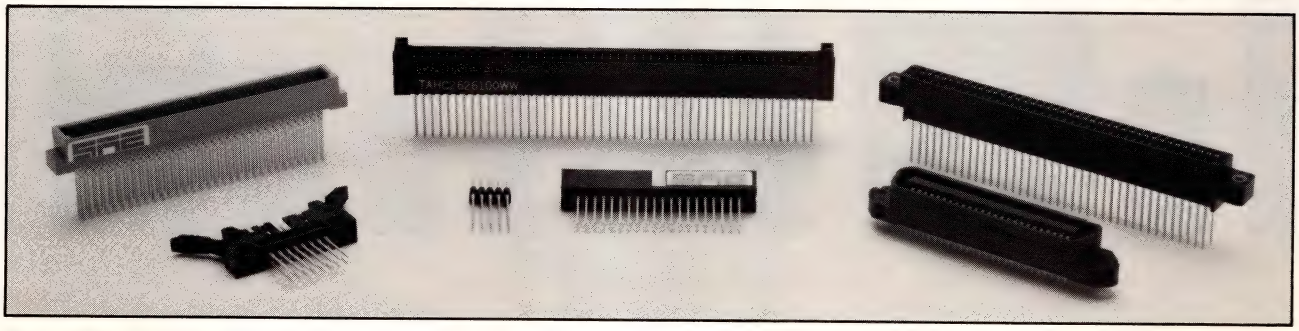
Circle No 402

68020 PACKAGE

- *Executes breakpoints without altering program under test*
- *Runs at clock speeds to 16.67 MHz*

A 68020-specific pod for the company's µP-development system simulates the chip's bus architecture and prefetch characteristics at clock

Lock in Reliability With SAE Pressfit Connectors.



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CIRCLE NO 174

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0.013% basic ohms accuracy (1 Yr.)		0.008% basic ohms accuracy (1 Yr.)	
Resolution to 1μV dc, 10μA dc, 1mΩ		Resolution to 100nV dc, 1μA dc, 100μΩ	
One-year specifications and warranty		Two-year specifications and warranty	
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8840A-05 IEEE-488 Interface	$150	8842A-05 IEEE-488 Interface	$150
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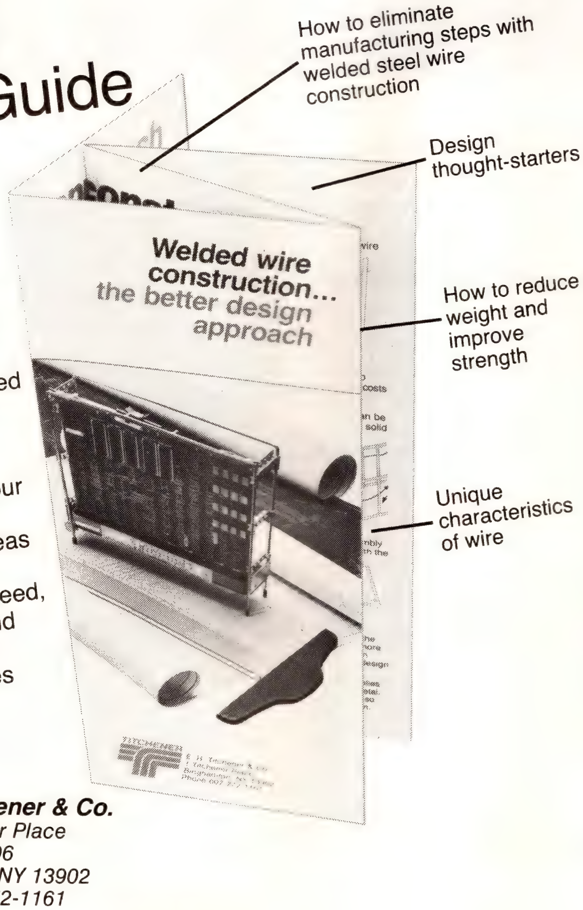
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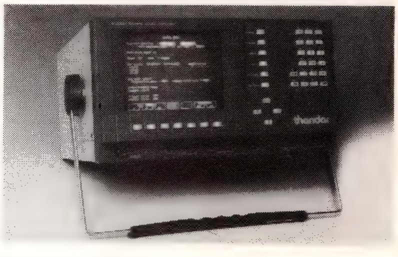
CIRCLE NO 177

speeds to 16.67 MHz. A complete setup includes the pod, the company's DE-1000 emulator module, and a host computer (IBM PC, VAX, or MicroVAX). The emulator has eight hardware breakpoints. The pod inserts the 68020's breakpoint op code into the µP's prefetched instruction stream in real time without modifying your program in memory. The pod will execute breakpoints regardless of the width of the data or instruction the µP is fetching. A 68020 pod, DE-1000 emulator, and MS-DOS software costs $15,295.

Emulogic Inc, One Edgewater Dr, Brookside Park, Norwood, MA 02062. Phone (617) 769-2980. TLX 710-336-5908.

Circle No 403



LOGIC ANALYZER

- *Provides 32 channels and a sampling rate of 100 MHz*
- *Has 4-level trigger sequencer with event count and delay*

You can configure the TA2000 portable logic analyzer to capture 32 data channels at 25 MHz, 16 data channels at 50 MHz, or 8 data channels at 100 MHz. The corresponding memory depths are 1k bits/channel, 2k bits/channel, and 4k bits/channel. For any configuration, you can set four channels to capture glitches as short as 5 nsec. The instrument has two movable cursors and one fixed cursor. You can display 17 channels of captured data as a timing diagram, or you can display all 32 channels as a list in binary, hex, decimal, or ASCII code. The analyzer has a reference memory that you can load either from the capture memory or

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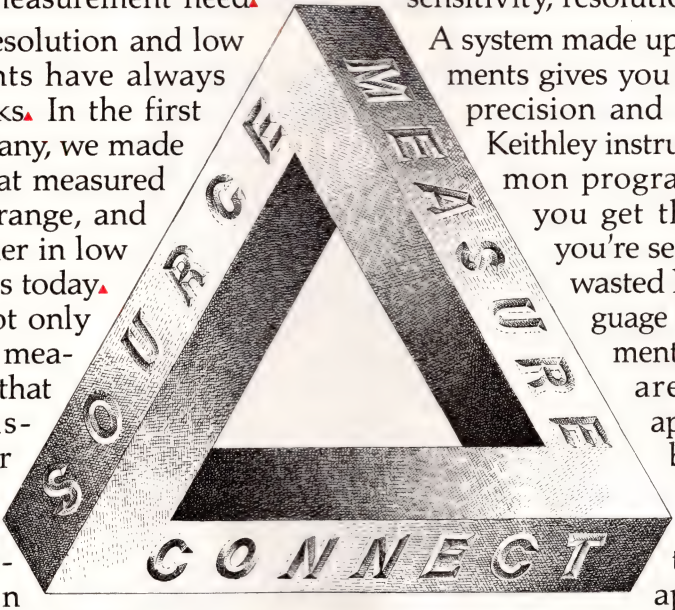

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KEITHLEY

CIRCLE NO 178

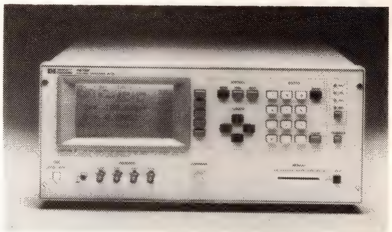
via the RS-232C or IEEE-488 interfaces. Disassemblers for Z80, 8085, 6502, and 6809 µPs are available (16-bit disassemblers are under development). £2950.

Thandar Electronics Ltd, London Rd, St Ives, Huntingdon, Cambridgeshire PE17 4HJ, UK. Phone (0480) 64646. TLX 32250.

Circle No 404

CAPACITANCE METER

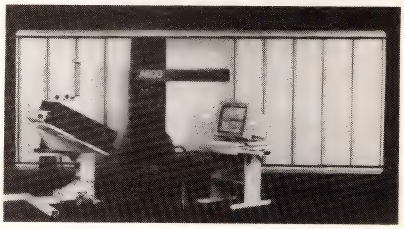
- *Provides high-frequency stimulus for chip capacitors*
- *Tests capacitors in 7 to 19 msec*



Model HP 4278A measures the capacitance, conductance, dissipation factor, quality factor, and equivalent series resistance of ceramic and film capacitors. Besides supplying the usual, relatively low, capacitance-meter test frequency of 1 kHz, the tester offers an optional 1-MHz test frequency. The test signal ranges from 100 mV rms to 1V rms in 100-mV steps. The maker claims that the instrument can test a capacitor in 7 to 19 msec. The tester specs 0.05% accuracy for capacitance measurements and 0.0002% accuracy for dissipation-factor measurements. The instrument sports an LCD. An interface to a device handler or to an IEEE-488 system is optional. $7000. Delivery, six weeks ARO.

Hewlett-Packard Co, Inquiries Manager, 1820 Embarcadero Rd, Palo Alto, CA 94303. Phone local office.

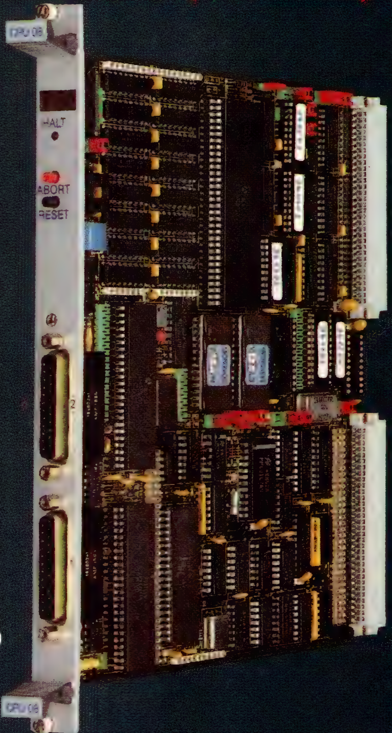
Circle No 405



MIXED ATE

- *Handles mixed-signal devices*
- *Generates digital stimuli at 25 MHz, analog stimuli at 10 MHz*

The A500 analog-digital ATE tests semiconductor devices, such as digital-signal processors or digital TV chips, that have both digital and analog functions. The tester can have 80 digital I/O pins and 16 analog I/O pins. You can choose from a variety of digital-vector memories and arbitrary-waveform generators. For example, a 256-kHz waveform generator features a 100-dB signal-to-noise ratio. The fastest digital



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- Up to 128 Kbyte EPROM
- Enlarged monitor and extensive selftest routines
- 1 parallel and 2 serial RS 232C/20 mA ports
- Programmable timer
- Real time clock
- 4 digit alphanumeric display on front panel
- P2-Piggybacks see below

CPU 09
identical features as CPU 08 except: 512 Kbyte (1024 Kbyte) dual ported DRAM

CPU-Piggybacks-P2
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- SAS 02 - SASI Interface
- DMA 01 - Direct Memory Access
- LOC 01 - Local Bus Interface (Proprietary)
- IEC 02 - GPIB/IEEE - 488 Interface
- SCS 01 - SCSI Interface (Option: DMA 68450)
- SIO 03 - 4 Channel Serial Interface

CPU-Options
- FPP 03 - Floating Point Processor 68881
- MMU 01 - Memory management unit with 68451, 68010/10 MHz
- MMU 02 - Memory management unit 68451, 68010/10 MHz incl. 68881 FPP
- MMU 03 - Memory management unit with 2 68451, 68010/10 MHz

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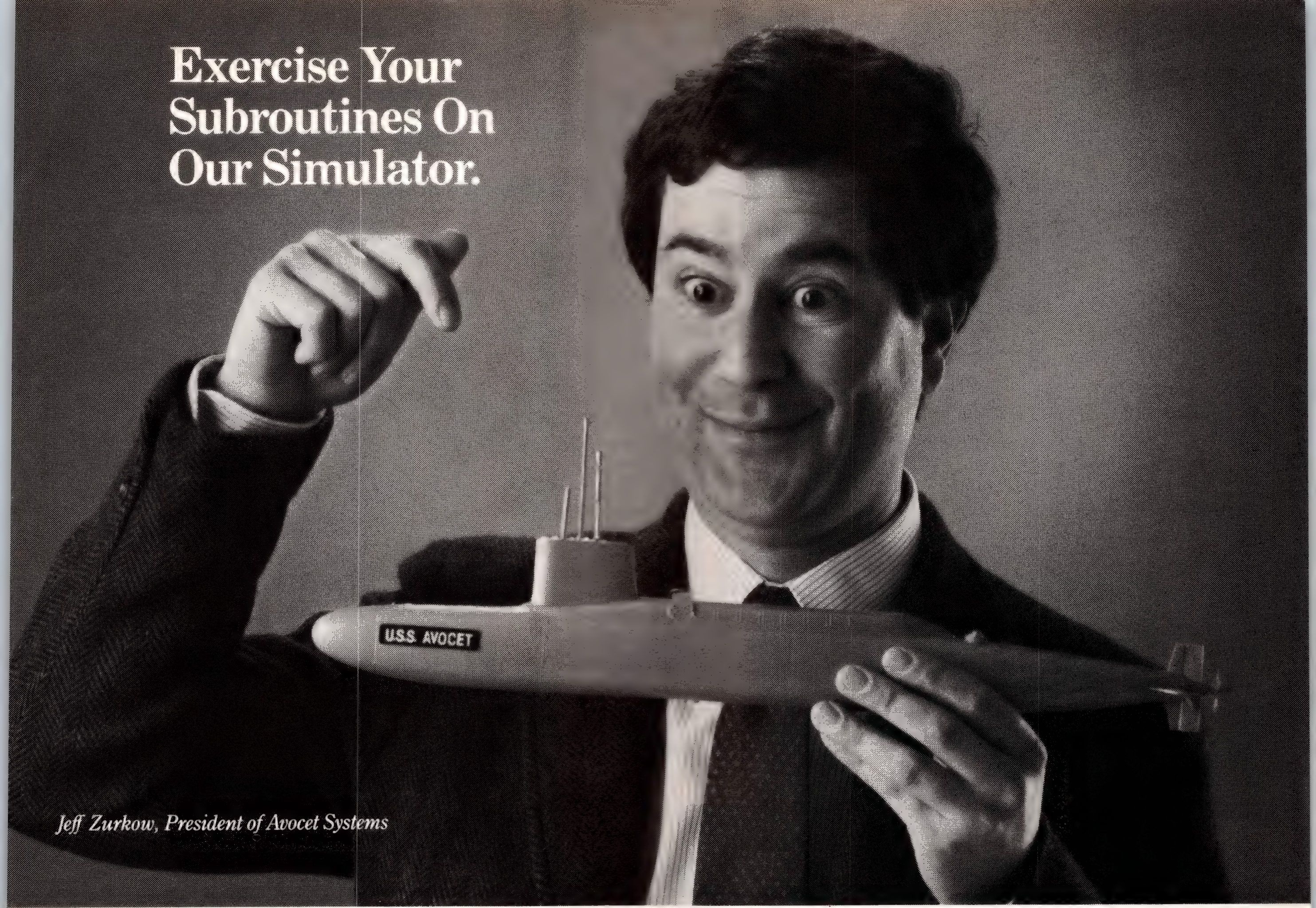

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SYSTEMS, INC.

CIRCLE NO 180

source runs at 25 MHz (50 MHz mulitplexed), and the fastest analog source runs at 10 MHz. The proprietary tester software runs under Berkeley Unix 4.2. $850,000 to $2,000,000.

Teradyne Inc, 321 Harrison Ave, Boston, MA 02118. Phone (617) 482-2700. TWX 710-321-1055.

Circle No 406

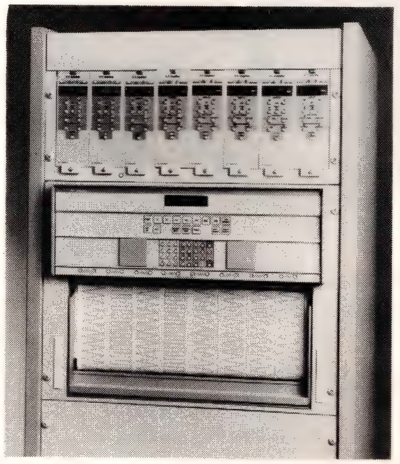
DIGITAL THERMOMETER

- *Unit fits in shirt pocket*
- *Measures room temperature as well as probe temperature*

The DT-160 pocket-sized digital thermometer measures 0 to 159.8°F. It has a temperature sensor mounted on its front panel. The sensor allows you to select a display of room temperature or probe temperature. The unit also has a built-in clock and a built-in tilt stand. You can program the unit to sound an alarm if it senses temperature excursions beyond either of two preset limits. $45.

A W Sperry Instruments Inc, 245 Marcus Blvd, Hauppauge, NY 11788. Phone (516) 231-7050.

Circle No 407



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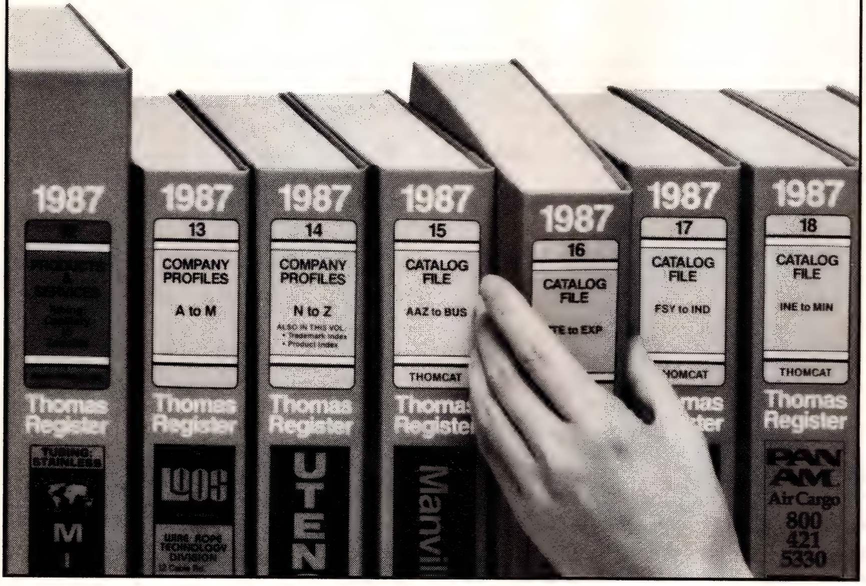

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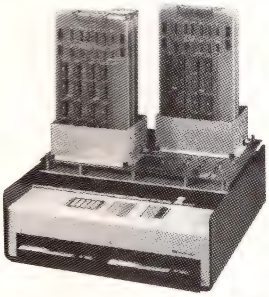

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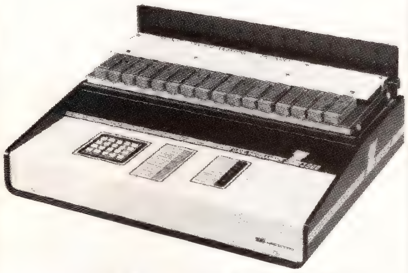

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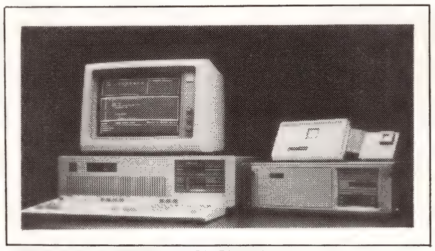

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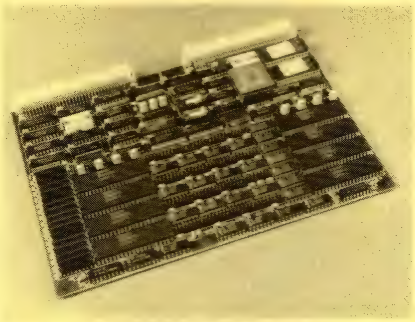

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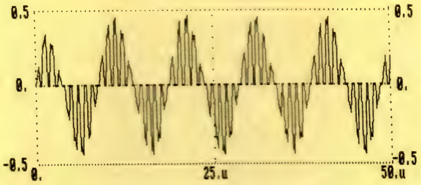

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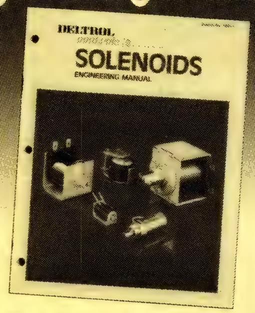

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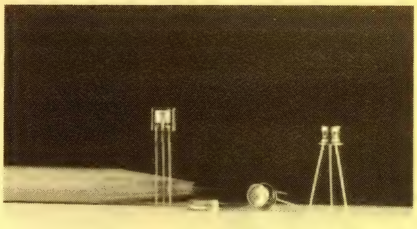

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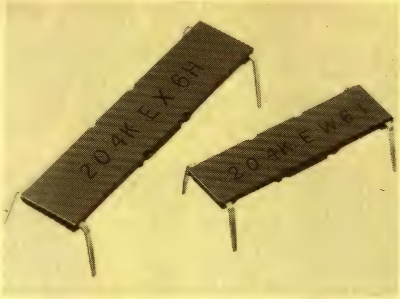

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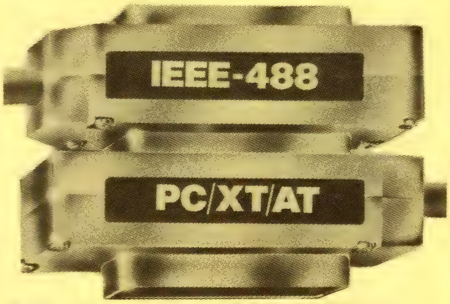

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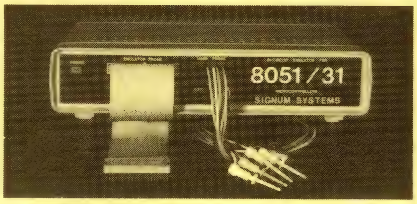

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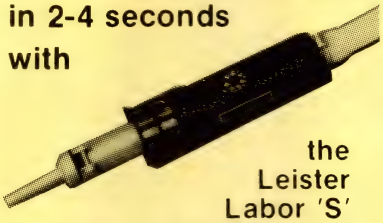

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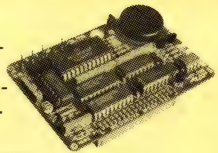

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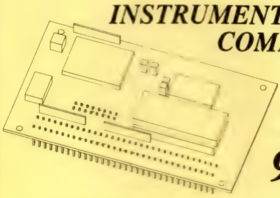

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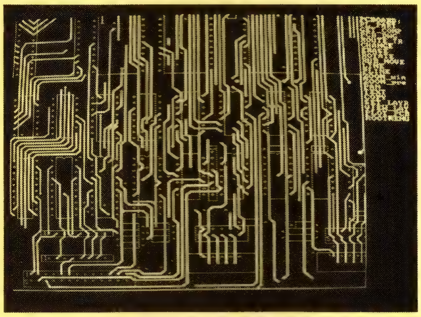

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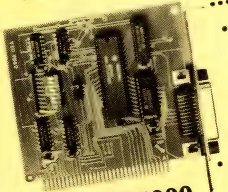

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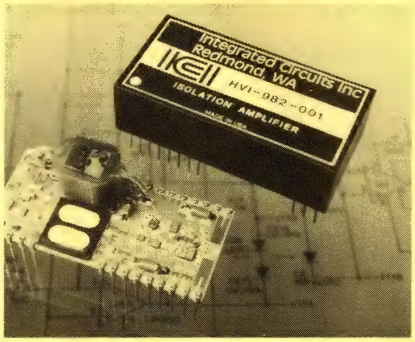

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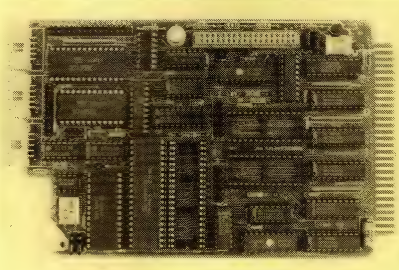

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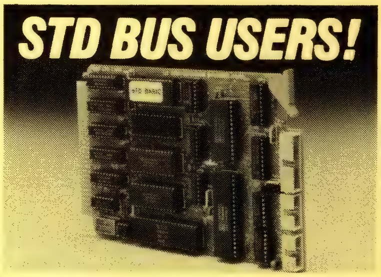

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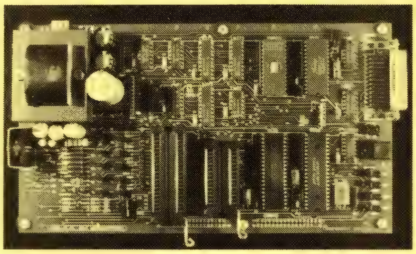

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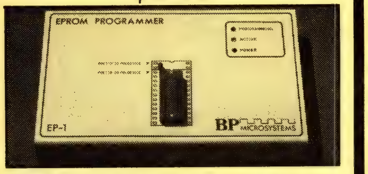

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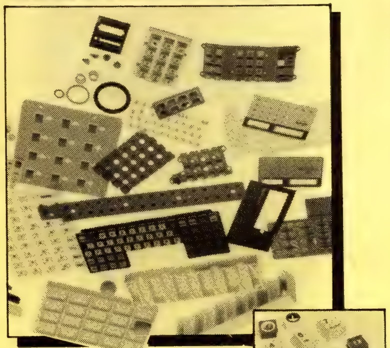

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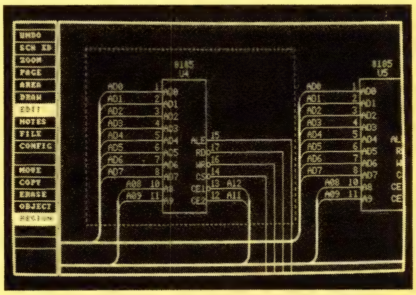

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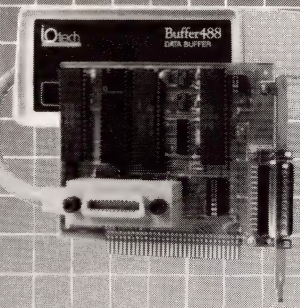

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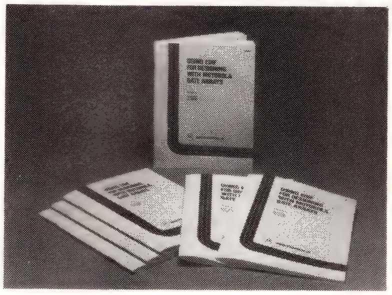
How to connect a plotter to a VAX

Application Note 229-14 details how to connect an HP plotter or film recorder to a Digital Equipment Corp VAX. For the less-experienced user, it explains how the VAX and the plotter commmunicate through a standard VAX RS-232C port. Guidelines help you choose the right cables for stand-alone or eavesdrop configurations for different plotter models.

Hewlett-Packard Co, 1820 Embarcadero Rd, Palo Alto, CA 94303.

Circle No 412



Guide for EDIF users

Using EDIF For Designing With Motorola Gate Arrays (BR357/D) is a functional-specification and user guide for the first version of the company's software using the Electronic Design Interchange Format (EDIF). It describes the information that the company will supply in an EDIF-based ASIC library and the information it needs to build an ASIC device specified by an EDIF file.

Motorola, Literature Distribution Ctr, 616 W 24th St, Tempe, AZ 85282.

Circle No 413

App note details high-density digital recorder

Synchronous Data Transfer from a High Density Digital Recorder examines the problems that occur when reproducing data. It discusses how Data-on-Demand, a feature of the company's SE9000 high-density, digital record/reproduce system, can synchronize data output from a recorder with a demand clock supplied by the user. The technical paper also describes the SE9000 configuration.

Thorn EMI Technology Inc, 8601 Dunwoody Pl, Atlanta, GA 30338.

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App note covers T1 error measurements

This 6-pg application note features testing applications, typical test configurations, and product information on T1 bit-error-rate (BER) monitoring and analysis. It provides tutorial data on out-of-service BER analysis, error measurements, T1 signal formats, and monitoring in-service T1 signals.

Intelco Corp, 8 Craig Rd, Acton, MA 01720.

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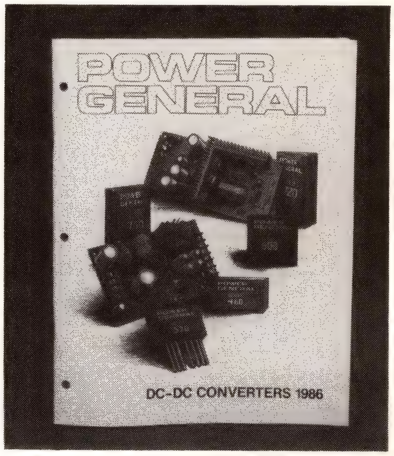

Handbook documents line of dc/dc converters

This 64-pg handbook includes comprehensive data on the company's complete line of dc/dc converters. Selection tables list the converters' characteristics. The book also provides a glossary of dc/dc-converter terminology and information on the theory of operation and application of converters.

Power General, Box 189, Canton, MA 02021.

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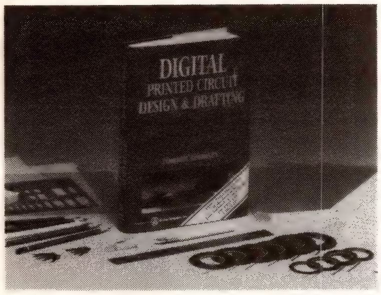

Book and kit aids in pc-board design

This combination package includes a 432-pg hardcover text and a kit of more than 480 design and drafting aids for performing the actual pc-board artwork exercises in the text. The book, *Digital Printed Circuit Design & Drafting*, features more than 450 photos, charts, and illustrations; how-to drafting techniques; and an appendix with tables, check lists, graphic symbols, terms, and definitions. It also guides the reader through the creation of artwork for 3- and 6-IC digital boards, a 10-IC digital/analog board, and a 10-IC multilayer board using the kit of drafting aids. Combination package, $99 ($9 postage and handling, $20 for surface freight outside the US); book or design-aid package, $49.95 each (postage and handling, $5 each).

Bishop Graphics Inc, Box 5007, Westlake Village, CA 91359.

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Newsletter covers changes to military standards

The October 1986 edition of the monthly *DDC News* discusses how the recent changes to MIL-M-38510, MIL-STD-883, and MIL-STD-454 affect military-equipment manufacturers. The 6-pg newsletter also describes several products, including interface cards to the 1553 data bus, the BUS-63105 MIL-STD-1553 transceiver, and the BUS-63125 transceiver.

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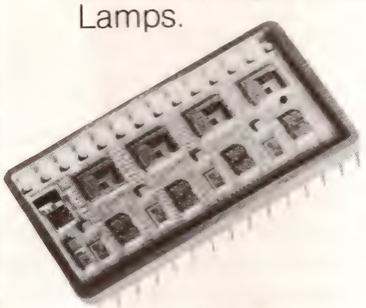

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NEW BOOKS

Electronic Speech Recognition, edited by Geoff Bristow. 395 pgs; $48.50; McGraw-Hill Book Co, New York, NY, 1986.

This reference guide, a companion volume to *Electronic Speech Synthesis*, is divided into three sections: techniques, technology, and applications. The section on techniques introduces the principles and methods of speech recognition. The chapters on technology give an overview of the state-of-the-art devices and systems available, and the section on applications is a collection of design experiences written by groups who have already applied the technology.

Basic Operational Amplifiers, by J C C Nelson. 113 pgs; $16.95; Butterworths Publishers, Stoneham, MA, 1986.

Written with the assumption that the reader has a fundamental background in circuit theory, this book includes Basic programs that relate directly to the introductory text on operational amplifiers. The programs use commands that are available on almost all implementations of Basic and should run on any machine that offers this language. All the programs have been thoroughly tested.

A Practical Introduction to the New Logic Symbols, 2nd edition, by Ian Kampel. 176 pgs; $19.95; Butterworths Publishers, Stoneham, MA, 1986.

The new logic symbols offer you a more efficient method of representing logic functions at any desired level. This edition instructs you in the intricacies of the new symbology and provides a practical example of how you may use the symbology to represent a circuit at different levels of engineering, from system level down to circuit level. The introduction of the new logic symbols takes into account the latest developments both in the fields of digital electronics and computer-aided drafting.

Computers in Systems for Measurement and Control, by Dag Björklöf. 286 pgs; $25; Daxab Eductronics, Box 102, S-181 22, Lidingö, Sweden, 1986.

This book teaches you how to understand and effectively use a personal computer in technical applications. It serves as an information guideline for engineers as well as a complete textbook for technical students. It includes information on computers and their role in technical systems; instrumentation and system techniques; computer inter-

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facing and communication; digitizing measurement signals; I/O management by computers; and Basic programming for measurement, analysis, and control. The book also contains numerous Basic programs.

Time-Domain Measurements in Electromagnetics, edited by Edmund K Miller. 536 pgs; $49.95; Van Nostrand Reinhold, New York, NY, 1986.

This book encompasses the development, technology, applications, and related signal-processing issues of time-domain measurements. Four sections and an appendix comprise this edition: The first section covers the background, present status, and future directions of time-domain technology including the educational advantages it brings to electromagnetics. The second section teaches you the basic components that go into a time-domain measurement system. The third section includes representative examples of time-domain measurements for various applications, and the fourth section treats signal processing problems associated with transient waveforms. Some of the topics included are short-pulse voltage sources, wide-band antennas, instrumentation, typical system configuration, materials measurements, exploration of inaccessible media, and signal processing and parameter estimation.

Selected Papers in Multidimensional Digital Signal Processing, edited by the Multidimensional Signal Processing Committee of the IEEE Acoustics, Speech, and Signal Processing Society. 484 pgs; $45.95; IEEE Press, New York, NY, 1986.

This book is a collection of 41 papers that summarize the state of the art in multidimensional digital-signal processing (MDSP) theory and the applications of MDSP to signal reconstruction, image processing, geophysical signals, and sensor-array processing. The book is organized into nine parts: The first four parts are theoretical, and the last five parts are application oriented. The introductory or survey nature of several of the papers makes the book suitable for self study.

Cases in Network Design, edited by William E Bracker Jr and Ray Sarch. 275 pgs; $26.95; McGraw-Hill Book Co, New York, NY, 1986.

Consisting of recent articles from *Data Communications* magazine, this book provides a state-of-the-art look at implementations of local and wide-scale networks in a variety of settings. The articles deal with several aspects of network design: They present information on what does and does not work in a given setting; they show alternative means of implementing networks by analyzing the tradeoffs and the relative costs; and they give an overview of the technological aspects and the impact of new technologies. The book covers networks installed for financial, transportation, communications, military, and distributed database-management applications.

Analog MOS Integrated Circuits for Signal Processing, by Roubik Gregorian and Gabor C Temes. 598 pgs; $49.50; John Wiley & Sons, New York, NY, 1986.

This book is both a working reference for industrial circuit design and a textbook; thus, you need have only a minimal background in mathematics and semiconductor physics. The book covers the theoretical and practical aspects of analog MOS integrated circuits, describing the operating principles of these circuits and showing you how to design and use them. It discusses the practical problems encountered in design, provides solutions, and presents some examples of actual system applications.

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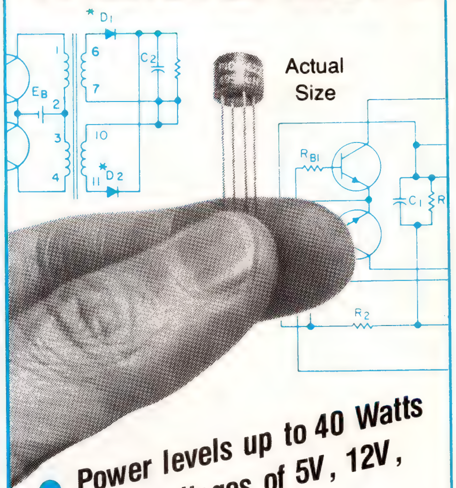

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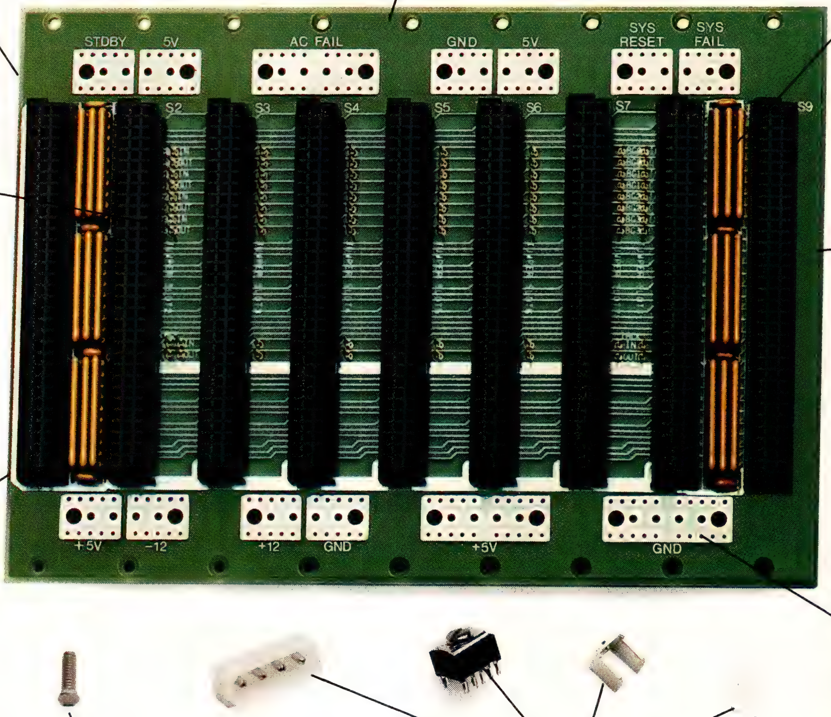

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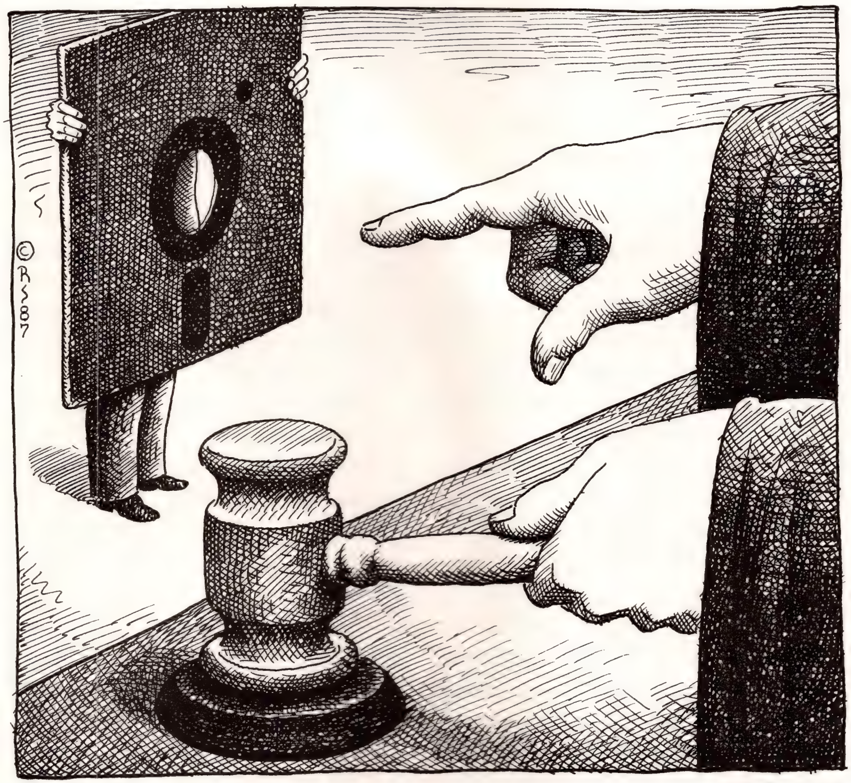

Rob Saunders

Software designers, who were once considered skilled tradesmen, are now beginning to be considered professionals by the courts as well as by the business community. This new perception of software designers as professionals has created potentially serious legal hazards for them: Like doctors and lawyers, software developers are now vulnerable to malpractice suits.

Claims of malpractice, which have sent insurance premiums for the legal and medical communities soaring, are devastating to professionals because, unlike lawsuits that are based on contract violations, malpractice suits allow for the recovery of a broad range of damages, including punitive damages.

Traditionally, legal opinion has held that software developers were essentially skilled tradesmen rather than trained professionals, because software design was an occupation with few national standards or formal degree programs to support it.

Now, however, professional standards for software design have been set forth by the Virginia-based Association of Data Processing Service Organizations (ADAPSO), certification programs have been administered and accredited by such organizations as the Institute of Certification of Computer Professionals, and formal degree programs for software design have been established at many universities.

The first sign of the changing legal status of software developers was evident 10 years ago. In 1977, a New York trial judge handed down a decision that for the first time equated the professional standing of software developers with that of architects and engineers. That case has become something of a sleeper: It went unnoticed for years, but has recently been widely cited as a precedent.

In the past two years, court cases based on flawed software have swelled in number and have been widely publicized. The suit involving software maker Lotus Development Corp (Cambridge, MA) and a Fort Lauderdale, FL, construction company attracted much media coverge. In that case (which was settled out of court in December on terms favorable to Lotus), James A Cummings Inc charged that Lotus's Symphony spreadsheet miscalculated by more than $250,000 the costs of a construction bid Cummings was preparing. Lotus contended that the company was at fault for using the program incorrectly.

Important software cases

The Lotus case received the lion's share of attention from the media, but other cases that the courts have been hearing will have an equally dramatic effect on software developers and their employers. Last fall, for example, in deciding what was expected to be a run-of-the-mill breach-of-contract suit between two businesses, an Indiana court surprised the legal community by finding that one of the parties—a custom-software maker—had committed malpractice.

The case had begun after L H Smith Oil Corp refused to pay the outstanding portion of a sum it owed Data Processing Services (DPS), a custom-software vendor. DPS had designed custom accounting software for Smith Oil to run on its IBM System/32 and System/34 mainframe computers. Smith Oil claimed the software was defective, and consequently it refused to pay the balance. DPS sued the oil company, and the oil company countersued, charging that the software was poorly designed.

The judge not only ruled that Smith Oil had no obligation to make the final payment, but he also ordered the software company to pay its former client damages for the defective system. Agreeing with the client that the accounting software was defective, the judge chastised DPS for agreeing to design accounting software when it had no experience in the area. The court issued a warning to DPS, reminding the company of its obligation to represent its abilities properly to potential clients. By virtue of its claiming to be a software-design firm, the judge ruled, DPS implied that it possessed certain skills and adhered to a set of standards shared by other members of its profession. As a result, the company's inability to adhere to these standards amounted to negligence.

> *The stir over potential malpractice suits is causing many software developers and their employers to adopt new means of protecting themselves.*

The judge found DPS's actions to be essentially unscrupulous, but other members of the industry took the verdict as a warning, realizing that even scrupulous business practices might not be enough to protect them from litigation. The stir over potential malpractice suits is causing many software developers and their employers to find new means of protecting themselves.

Their main method of protection is the contract. Unlike the sale of goods, the sale of services is not tightly regulated on either the state or the federal level. In the absence of such regulations, a well-crafted contract can limit a company's legal exposure. As a result, many software developers, like other purveyors of services, try to protect themselves through contract provisions such as carefully worded limitations on the extent of their responsibility in case of a negligence charge. These provisions, they hope, will offer some measure of protection against malpractice claims. The responsibilities of subcontractors or other third parties are also being stipulated in contracts.

Besides contractual provisions, another method of self-preservation software designers are employing is to present clients with an outline of the different approaches they could use to solve a design problem. Clients review the outline and then select the solution that seems the most sound. This way, if a client later becomes dissatisfied with the design or charges negligence, the review and written approval of the solution places at least some of the responsibility on the client.

Another means of protection is specialized insurance. Malpractice insurance, which is usually associated with lawyers and doctors, is now becoming available for software makers and their employees. Known as "errors and omissions" insurance, such policies cover injuries or property damage that result from computer failure as well as any damages that result from unauthorized access to the computer system.

Among electronics companies, malpractice insurance is still rare, and only a handful of insurance carriers offer such policies. Unlike malpractice insurance for physicians, though, who carry policies in their own names, malpractice coverage in the electronics industry is purchased by companies and protects the corporate entities as well as their employees.

Electronics malpractice premiums have yet to reach the astronomical levels that have caused loud protests in the medical profession. Premiums for electronics companies typically range from $5000 to $25,000 per year, according to Robert Middleton, director of the electronic insurance division of Armfield, Harrison and Thomas Inc, a Leesburg, VA, insurance agency. For software companies, the costs vary, depending on the kind of software the company specializes in. Malpractice coverage for makers of mass-produced, shrink-wrapped programs is generally easier to obtain than is coverage for custom-software makers. **EDN**

Author's biography

Richard Beutel is an attorney with Abrams, Westermeier & Goldberg, a Washington, DC, computer-law firm specializing in software law. Prior to joining the firm, he practiced law for two years in Silicon Valley. Beutel earned a JD at Georgetown University Law Center (Washington, DC) and a BA at Pomona College (Claremont, CA).

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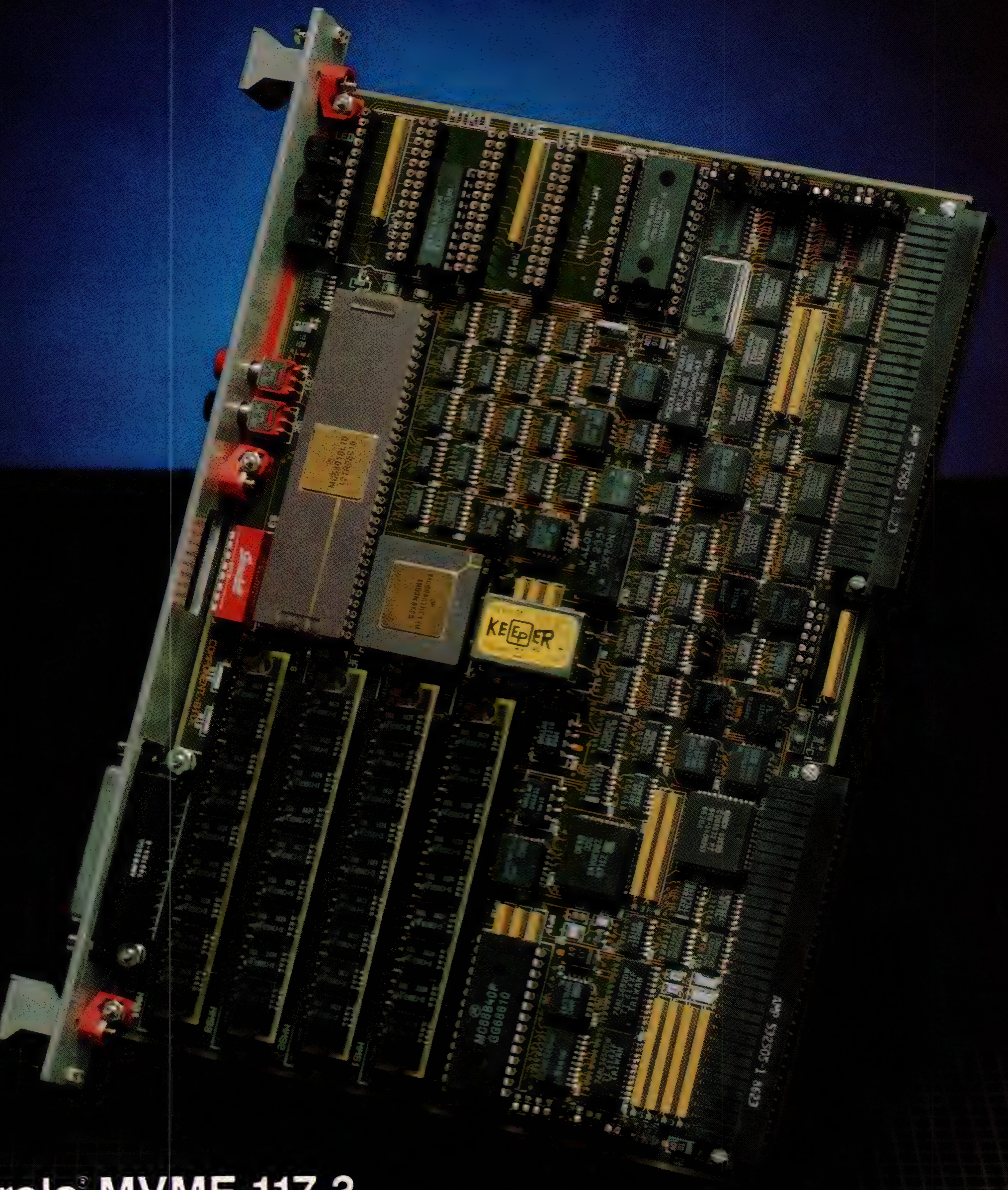

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Issue Date	Recruitment Deadline	EDN Editorial Emphasis	EDN NEWS
Mar. 18	Feb. 26	CAE; ASICs; Electro '87; Show & Product Preview	Closing: Feb. 18 Mailing: Mar. 26
Mar. 31	Mar. 10	Electro '87 Show Issue; Design & Development Tools; ICs & Semiconductors	
Apr. 15	Mar. 26	Microprocessor Technology; Software Development; Digital ICs	
Apr. 30	Apr. 9	Communications Special Issue; ASICs; Test & Measurement	Closing: Apr. 2 Mailing: Apr. 23
May 14	Apr. 23	Analog Technology Special Issue; ICs; Test & Measurement	
May 28	May 7	Computer Peripherals; Software; Power Sources/Devices	Closing: Apr. 30 Mailing: May 21
June 11	May 21	Math ICs; CAE; Computers	
June 25	June 4	ASIC (Semicustom ICs) Directory; Analog ICs; Surface-Mount Technology	Closing: May 28 Mailing: June 18
July 9	June 18	Product Showcase-Volume 1; ICs & Semiconductors; Software	
July 23	July 2	Product Showcase-Volume II; Computers & Peripherals; Test & Measurement Instruments	Closing: June 25 Mailing: July 16
Aug. 6	July 16	Computer Boards; Digital Signal Processing; Test & Measurement; Top Ten Reader Vote Contest	Closing: July 23 Mailing: Aug. 13

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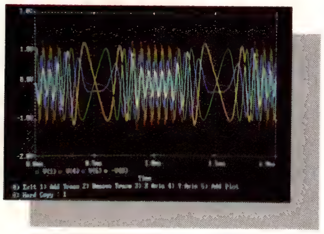

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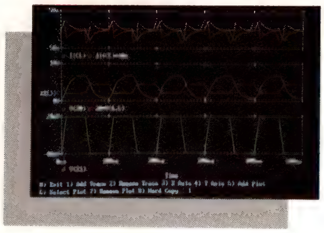

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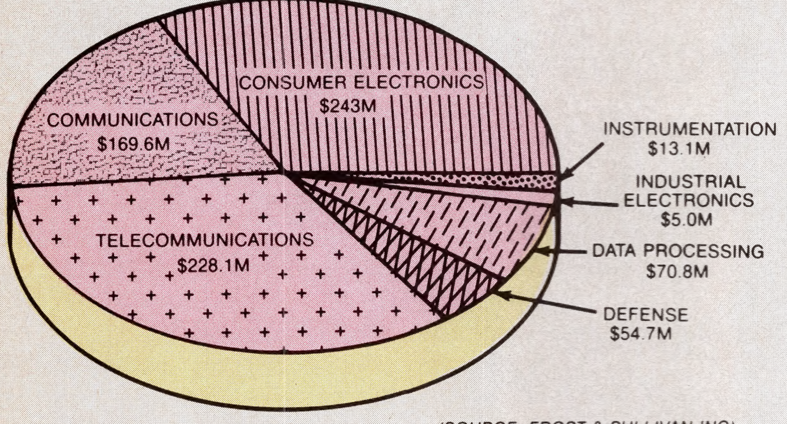
LOOKING AHEAD

EDITED BY GEORGE STUBBS

FORECAST OF SMD CONSUMPTION BY APPLICATION—1987



(SOURCE: FROST & SULLIVAN INC)

Use of SMDs to triple in Europe by 1991

Demand for surface-mount devices (SMDs) by European manufacturers will triple during the period from 1986 to 1991, reports Frost & Sullivan Inc, a market-research company with main offices in New York City and London. The European market for SMDs in 1991, says F&S, will approach $2 billion.

Europe has yet to follow Japan's early, large-scale development of surface-mount technology, according to F&S, because the types of products the technology best suits were not being produced in Europe in great quantities. This situation is beginning to change, however. Principal areas of SMD development in Europe are small appliances and TV assemblies, radio communications equipment (especially cellular radio), main telephone exchange equipment, and defense and data-processing applications.

The 1986 market for SMDs in Europe climbed to $657 million (US dollars); in 1991, it will be worth $1.9 billion. According to F&S, West German manufacturers accounted in 1986 for more than a quarter of the consumption of SMDs ($187 million), United Kingdom companies nearly one-fifth ($124 million), and French concerns less than 15% ($92 million). The French are expected to increase their use of SMDs at a faster rate than other nations' manufacturers.

F&S also predicts that, though today SMDs account for less than 10% of all electronic components, almost 20% of all such components will be SMDs by 1991. Well over 25% of all capacitors and more than 20% of all ICs will be rendered in surface-mount form. Many inductors and resistors will also appear as SMDs. In volume terms, ICs currently account for nearly 75% of SMD sales in Europe.

Advanced ceramic products to be worth $6B+ by 1995

The market for advanced ceramic products will approach $2 billion in 1987 and should easily exceed $6 billion in 1995, according to the market-research company International Resource Development Inc of Norwalk, CT. Electronic components will continue to lead the way in shipments of advanced ceramic products throughout this period, but in the late 1980s mechanical applications—particularly heat-engine components—will play a more significant role in market growth.

For electronic components, says IRD, plastic materials often outperform and undercut the price of advanced ceramic materials, but an end to such dominance is in sight. The reliability, capacity, and versatility of advanced ceramics are well suited to the increasingly sophisticated tasks that ICs are required to perform, and manufacturing with ceramics is becoming more economical. Advanced ceramic materials have excellent thermal conductivity, and the development of substrate materials for applications that require high thermal conductivity will further enhance the attractiveness of advanced ceramics.

High-resolution-CRT market to be worth $2B by 1990

Shipments of high-resolution monitors in the US will continue to increase by an average annual rate greater than 35%, reports the market-research company Venture Development Corp (Natick, MA). In 1990, the market for high-resolution CRTs will be worth at least $2 billion. This growth will be driven by the changing needs of personal-computer users; as more sophisticated functions move to the desktop level, says VDC, PC users will demand monitors with higher resolution than is currently available.

Personal computers are now powerful enough to handle CAD/CAM, medical imaging, desktop publishing, and other applications requiring complex graphics. In response to the demands of PC users, monitor manufacturers that previously sold only to OEMs are starting to package their products for sale to end users. Aydin Controls, Mitsubishi, and GE/RCA are among the leaders in this change in marketing tactics.

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Pass Band (MHz)	start, max.	41	90	133	185	290	395	500	600	700	780	910	1000
	end, min.	200	400	600	800	1200	1600	1600	1600	1800	2000	2100	2200
Min. 20dB Stop Frequency (MHz)		26	55	95	116	190	290	365	460	520	570	660	720

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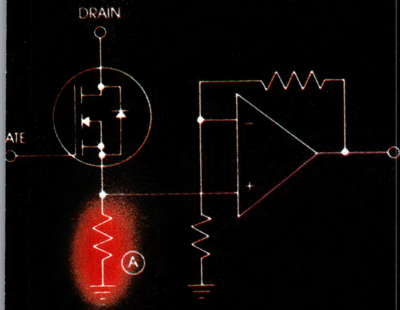
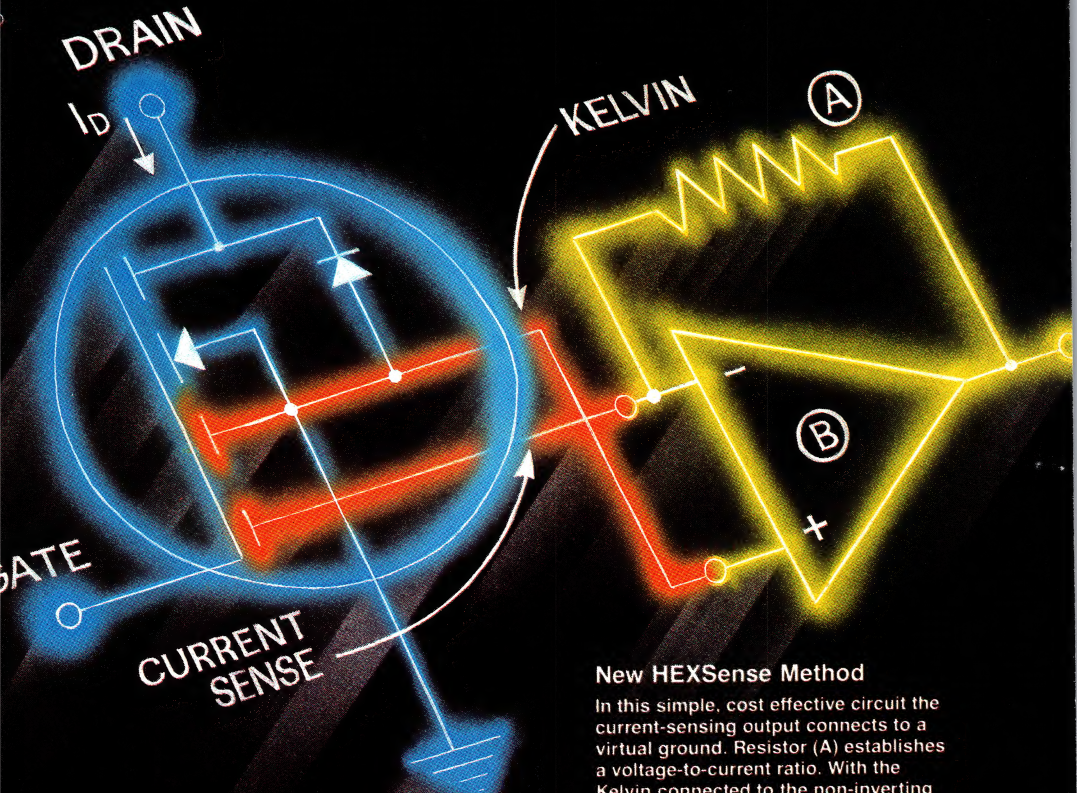


Old Method

This circuit uses a fractional value resistor (A) to measure current, causing a voltage drop which increases power losses. Its parasitic inductance also slows down switching speed. To offset these losses, a lower $R_{DS(ON)}$ power MOSFET may be used, increasing circuit cost.



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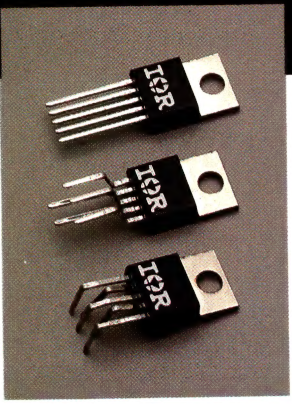

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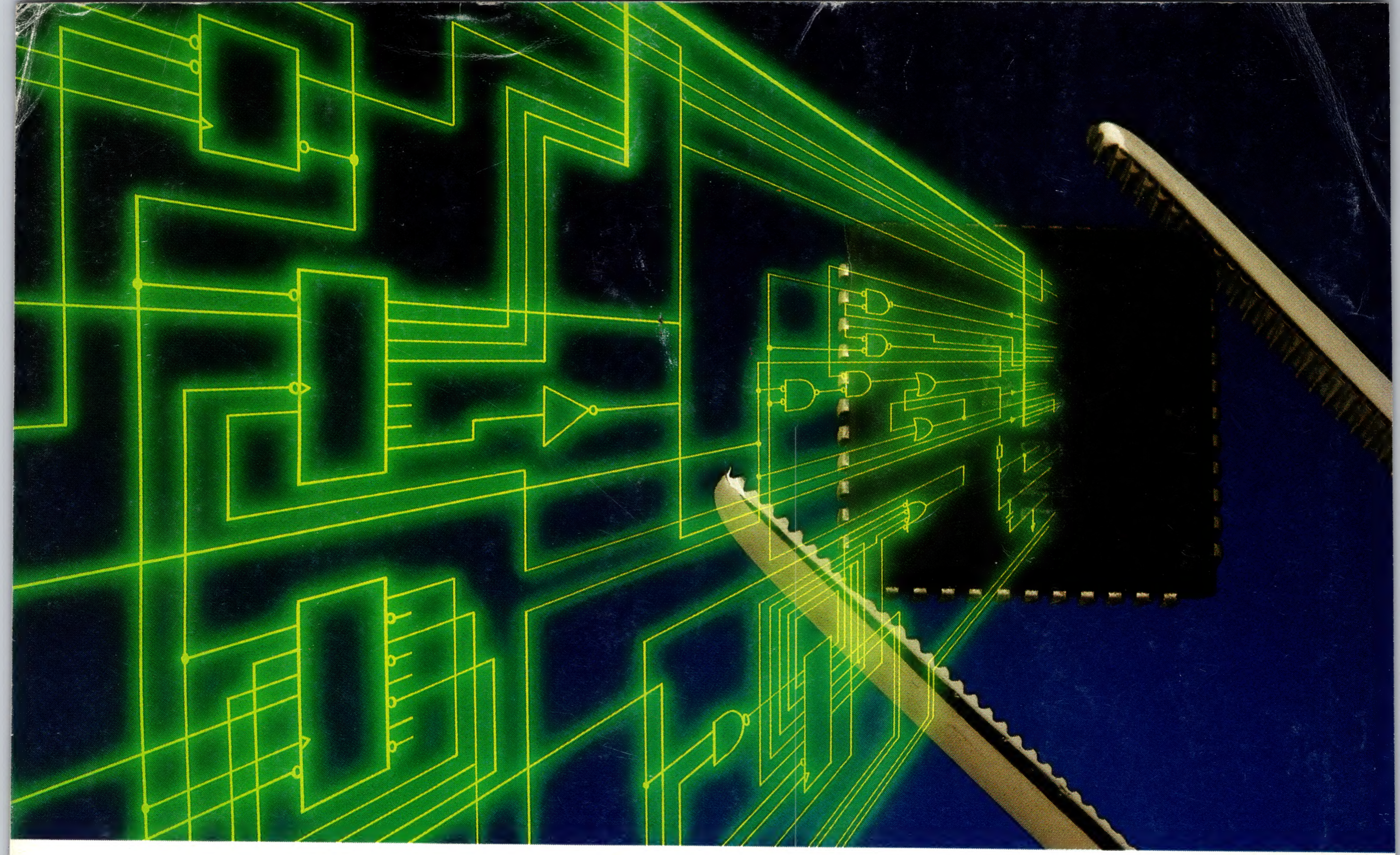

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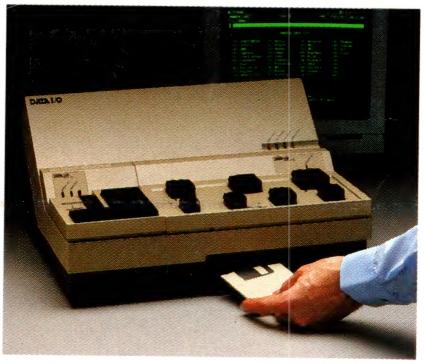

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